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# VALIDATION STUDY OF AN APPROACH FOR EVALUATING THE IMPACT OF A SHOPPING CENTER ON AMBIENT CARBON MONOXIDE CONCENTRATIONS

R. M. Patterson, et al

GCA Corporation

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16. ABSTRACT

This report describes the results of a joint traffic and carbon monoxide monitoring study conducted for 2 weeks at a regional shopping center, prior to Christmas 1973, and the application of observed data towards the validation of an early version of a proposed procedure to assess the air quality impact of indirect sources. Automatic traffic recorders were installed at all entrances and exits, and five carbon monoxide monitors were set up within the parking lot and at the main gate. Vehicle running time studies and wind speed and direction measurements were also undertaken at the site.

Peak hour calculated concentrations obtained using the proposed procedure correlated favorably with observations, but they averaged a factor of 2 higher than observations. Calculated values tend to overestimate concentrations at low wind speeds and underestimate concentrations at moderate wind speeds. Although there were an insufficient number of 8-hour observations, those that were obtained did not correlate with estimates obtained using the proposed procedure.

The results were discussed.

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by

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GCA Corporation
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Bedford, Mass. 01730

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# ABSTRACT

This report describes (1) the results of a joint traffic and carbon monoxide monitoring study at a regional shopping center, and (2) the application of these results towards the validation of a proposed approach to assess the air quality impact of shopping centers. Automatic traffic recorders were installed at all entrance and exit gates, and five carbon monoxide monitors were set up at likely upwind-downwind locations and at the main gate. Running time studies were made using pursuit vehicles. Wind speed and direction measurements were taken.

The data indicate that the proposed methodology underestimates the pre-Christmas peak-hour traffic volumes and overestimates the running times. However, the average emission density computed by the methodology is essentially equivalent to that calculated using data collected at the site. Peak-hour calculated concentrations correlate favorably with those observed, but they average a factor of two higher than those observed. There is a tendency for the calculated values to be overestimates for low wind speeds and underestimates at moderate wind speeds. The peak eight-hour calculated concentrations do not correlate with observed values. The complete data listings are given as appendices.

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## SECTION I

## INTRODUCTION

### BACKGROUND

As a result of legal action brought against EPA by the National Resources Defense Council, EPA has been directed to ensure that all State Implementation Plans be responsive to maintaining National Ambient Air Quality Standards. As a requisite step in fulfilling this requirement, EPA is currently developing guidelines to evaluate the impact of indirect sources on air quality; an indirect source being defined as one which, while not producing a significant amount of pollution itself, results in the generation of additional vehicular traffic and thus increases the pollution burden in its vicinity. Examples of such indirect sources are:

- Highways and roads
- Parking lots and garages
- Shopping centers
- Recreational centers and amusement parks
- Sports stadiums
- Airports
- Commercial or industrial developments

The purpose of this study was to evaluate a methodology proposed by EPA for estimating the maximum impact of one of the indirect source types, a shopping center, on ambient carbon monoxide levels in its immediate vicinity, and to provide a basis for modifying the methodology should the need for revisions be indicated. It is stressed that the methodology evaluated here is preliminary, and it is not necessarily in the form which will be provided in the EPA guidelines for the evaluation of indirect sources.

## APPROACH

In general terms, the problem of methodology validation and development was approached by:

1. Developing an empirical data base suitable for testing the proposed methodology.
2. Comparing observed concentrations to those predicted using the proposed methodology.
3. Reviewing the proposed methodology on the basis of the observed/predicted comparisons and a sensitivity analysis with a view toward possible improvements in methodology, and
4. Estimating, on a limited basis, the effect of suggested changes in methodology.

## CONTENT OF REPORT

Section II of this report summarizes the method proposed by EPA for assessing the maximum impact of a shopping center on ambient CO concentrations, and lists the inputs required for its use.

Section III describes the characteristics of the selected shopping center and its physical setting.

Section IV describes the traffic and air quality monitoring networks, including instrumentation and data handling procedures; and Section V summarizes the data collected by these networks.

Section VI contains the comparisons between observed concentrations and those predicted by the proposed EPA methodology, and discusses alternate approaches to impact assessment.

Section VII contains the principal conclusions and recommendations of the study.

The field data acquired during the study are presented as appendices. Appendices A, B, C, E, and F are tabulations of traffic, meteorological, and carbon monoxide concentration data. Appendix D contains sketches of the gate intersections at the shopping center, with calculated gate capacities. Appendix G is a sensitivity study of the proposed EPA methodology.

# SECTION II

# PROPOSED EPA METHODOLOGY FOR IMPACT ASSESSMENT

## SUMMARY OF ASSESSMENT METHODOLOGY

The assessment methodology as outlined by EPA[1] and GEOMET[2] reports takes into account the impact on air quality from three sources: (1) background CO levels, (2) total emissions from the Shopping Center Complex, and (3) emissions in the vicinity of congested exits. Thus the overall CO level predicted for a monitoring station by the model is given by

$$COT = COB + COL + COA \qquad (1)$$

where COT is total CO concentration (ppm)

COB is the background CO level (ppm)

COL is the contribution to CO levels from emissions at a congested exit (ppm)

and COA is the contribution to CO levels from the overall shopping center emissions.

### Background Level

The background CO concentration at a proposed shopping center site may be determined by monitoring at the site to obtain a statistically valid sample. If this is not practical the background value might be estimated from the nearest monitoring stations or by diffusion modeling applied to an emission inventory of all nearby sources.

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## Total Emissions From the Complex

The contribution to CO concentration from the total emissions at the shopping center complex are determined from an estimate of the total CO emission for the area. These emissions are considered to be uniformly distributed over the total area of the complex and an area source diffusion model is applied to estimate the resulting concentration at a point within the complex. This diffusion model is represented graphically in Figure 1 of reference 1 which can be entered with the emission density (g/sec-$m^2$) for the complex and the distance to the upwind edge of the complex (m) to read out expected concentration (ppm).

The total emission density Q is determined from:

$$Q = \frac{ef\ V\ RT}{60\ A} \qquad (2)$$

where Q is emission density in g/sec-$m^2$.

ef is auto emission factor in g/min,

V is the volume of traffic drawn by the complex in vehicles/sec (each vehicle is counted separately for its entrance and exit to the complex),

RT is the typical running time of a vehicle in the complex in seconds,

A is the area occupied by the complex (including its parking lot) in $m^2$.

The emission factor used in this operation is based on an average mix of autos for 1974 and assumes light duty idling vehicles. A factor of 16.2 g/min[1,3] is appropriate.

The traffic volume, V, is the expected rate at which the complex will draw traffic. This number must be appropriate to the time period under study. For example the 1-hour peak traffic generation for the year will be used to estimate 1-hour peak CO levels. If the value of V cannot be provided by the developer it may be estimated from the equation provided in reference 1 relating peak traffic generation to expected average daily traffic for a shopping center. This equation is

$$V = 4.3 \times 10^{-5} \text{ ADT for week days,} \qquad (3)$$

and

$$V = 6.7 \times 10^{-5} \text{ ADT for Saturdays,} \qquad (4)$$

where V is the peak hourly volume and ADT is the average expected trip generation rate in trips per day.

The vehicle running time (RT) is the total time required for a vehicle to enter or exit the complex and obtain, or leave, a parking space. This time is the sum of three factors: (1) base running time (BRT), which is the base time excluding delays due to congestion or traffic signals; (2) added running time due to congestion (ART) which is the time spent waiting in exit or entrance queues; and (3) added running time due to traffic lights (C) which is the time spent at traffic signal delays. These factors are combined to estimate overall running time:

$$RT = BRT + ART + C \qquad (5)$$

with:

$$ART = b \frac{a}{1 - a} \qquad (6)$$

where a = utilization factor, and
b = average outflow time per vehicle

and C = 0.5 x fraction of signal cycle on red x length of signal cycle. Under this formulation the value of ART is based on classic queuing theory; however, to exclude unlikely effects at extremes of congestion, the value of ART is limited to 20b when the utilization factor exceeds 0.95.

In the event that traffic volume exceeds the gate capacity or the complex's parking capacity, vehicle running times will increase markedly. To account for this increase, a correction factor based on number of parking spaces, size of complex, and traffic flow, has been developed. This factor, which is tabulated in Table 3 of reference 1, is applied to the overall emission density for the complex when the peak hour traffic volume exceeds the capacity of the parking lot. Thus the emission density, when parking or gate capacity is exceeded, is given by:

$$Q = \frac{ef\ V\ RT}{A}\ cf \qquad (7)$$

where cf is the correction factor of Table 3, reference 1.

## Emissions in the Vicinity of Congested Exists

The estimated contribution to CO concentration from emissions in the vicinity of a congested exit is based on a line source model representing the row of vehicles waiting at the congestion point. A line source diffusion model (HIWAY[4]) has been used to estimate the CO concentration resulting from this traffic line. Concentrations calculated by this model are presented graphically in Figure 2 of reference 1. The vehicle flow rate (gate capacity) and angle of wind to the roadway can be entered to the appropriate curve in Figure 2 of reference 1 to find the resulting roadside CO concentration.

The model assumes a vehicle emission factor that corresponds to idling autos and is based on the average 1974 mix of vehicles (16.2 g/min-veh[1,3]).

It also assumes the queue to include vehicles spaced with one-half auto length between cars so that the line source strength is given by:

$$Q_e = \left(\frac{16.2 \text{ g/min-veh}}{60 \text{ sec/min}}\right)\left(\frac{1}{10 \text{ m/veh}}\right) \quad (8)$$

$$= 0.027 \text{ g/sec-m}$$

## INPUT PARAMETERS

The following parameters are essential to the application of the above methodology. In the evaluation of a proposed complex these parameters must either be supplied by the developer or estimated from some other basis:

1. Background CO levels
2. Parameters related to the shopping center
    - gross leasable floor space
    - number of parking spaces
    - property dimensions
3. Parameters related to traffic control
    - traffic signal characteristics
    - number of gates and gate capacities
4. Parameters related to traffic flow
    - average trip generation rate
    - peak trip generation rate
    - vehicle base running time
    - traffic flow and distribution through gates

In addition to the above listed parameters, there are parameters implicitly assumed by the methodology. The most significant of these are the meteorological parameters assumed in the diffusion models. These models are based on a wind speed of 1 m/sec and a class D stability.

# SECTION III

## SELECTED SHOPPING CENTER — LIBERTY TREE MALL

To be classified as a regional shopping center according to current practices, a shopping center should:[2]

- Have a gross leasible floor space of at least 300,000 square feet
- Have a total acreage of at least 30 acres
- Contain at least one major department store
- Serve a population of at least 150,000
- Have open, peripheral parking

As would be expected, a cursory inspection of the shopping centers within the Greater Boston area showed a number of centers which met these requirements. Guidelines for screening these candidate centers were based largely upon the apparent suitability of the center for a monitoring study, principal features for consideration being relative freedom from confounding factors such as the presence of a major commuting route immediately upwind from the center or of other significant contributors to an ill-defined and variable carbon monoxide background, and the feasibility of monitoring both carbon monoxide concentrations and traffic parameters at key locations. Also, unusual topographical features at the site which might give rise to complicating small-scale atmospheric circulations were to be avoided, if possible.

The regional shopping center selected for the study was the Liberty Tree Mall located in Danvers, Massachusetts, approximately 20 miles north-northeast of Boston. The Mall primarily serves the "North Shore" region of Greater Boston, an area with a population in the vicinity of 500,000. It is situated within the northwest quadrant of the Route 128/ Endicott Street interchange as shown in Figure 1.

The Liberty Tree Mall has a gross leasible floor space of 867,000 square feet, of which 576,000 square feet are contained in an enclosed mall and 291,000 square feet are distributed among peripheral stores. This places the shopping center near the middle of the size range of regional shopping centers. (GEOMET [2] identifies this range as 300,000 to approximately 1,500,000 square feet.) The total area occupied by the shopping center is 95 acres, of which approximately 32 percent is presently undeveloped.

The mall is made up of two "anchor stores"—that is, major department stores that influence the makeup of the shopping center—and 53 smaller, diversified stores. The peripheral stores include a large discount furniture store, a supermarket, five small business establishments, and a theater. There are also several branch banks and businesses along two of the entrance/exit roadways.

The proximity of the Liberty Tree Mall to the existing highway (Routes 1, 114, and 128) and roadway system makes access relatively simple. Parking is provided by a semi-open, peripheral type system with a service road forming a loop around the enclosed mall. The capacity of the lot is 5,000 vehicles. Access and egress may be obtained through four gates, three of which are under traffic signal control.

A parameter frequently used in characterizing a shopping center is the number of parking spaces per 1,000 square feet of gross leasible store space. Calculation of this ratio for the Liberty Tree Mall yields a value of 5.8 when all leasible floor space within the shopping center (867,000 square feet) is included. The range given for regional shopping centers of this size by the Urban Land Institute[5] is from 5.03 to 7.30.

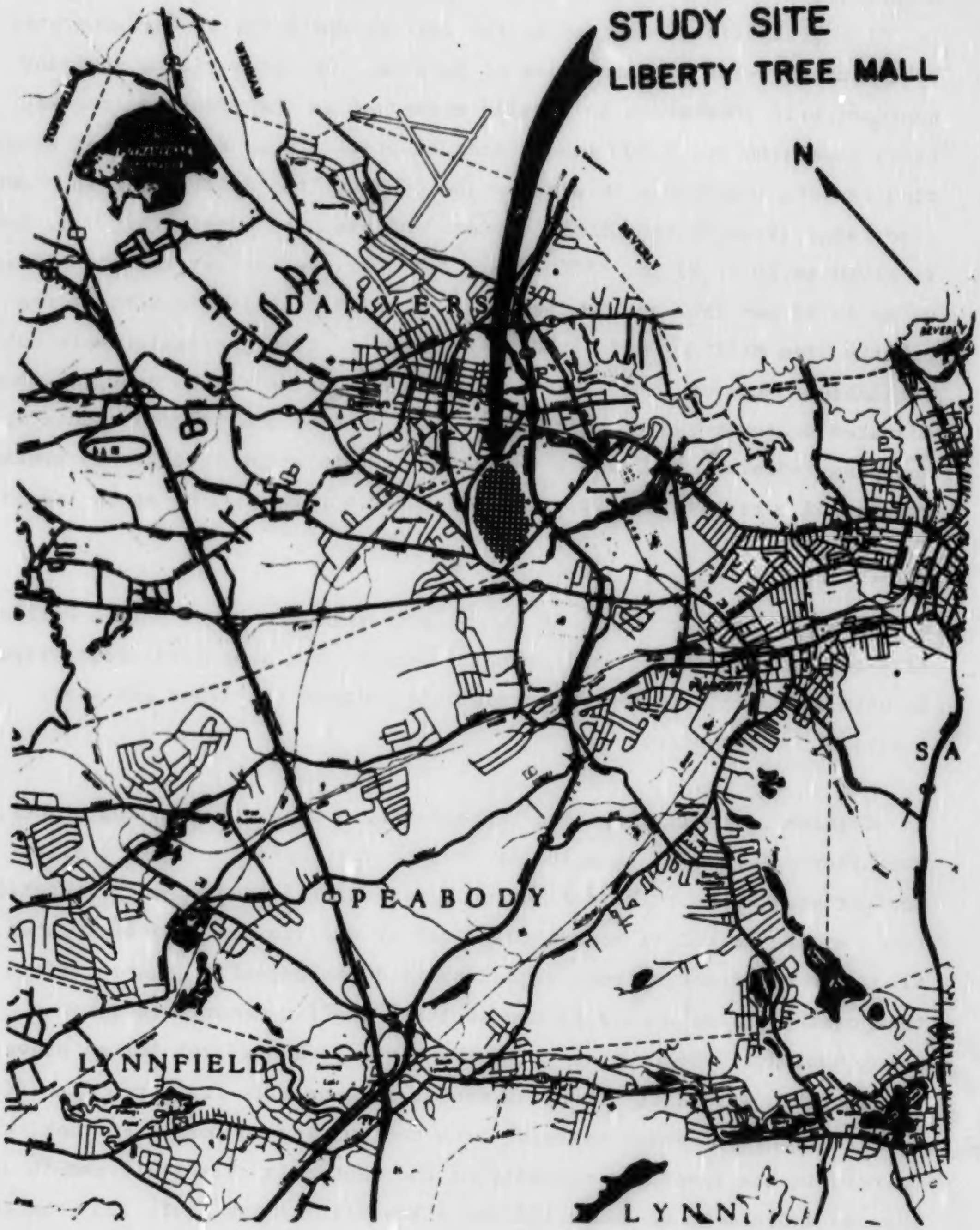
STUDY SITE
LIBERTY TREE MALL
N
DANVERS
PEABODY
LYNNFIELD
LYNN
SA
BEVERLY

Figure 1. Location of Liberty Tree Mall

A term descriptive of traffic activity associated with shopping centers is "trip generation," defined as the rate at which the center generates vehicular movements irrespective of purpose. In categorizing shopping centers, trip generation is usually expressed as the number of one-way trips generated per 1,000 square feet of store area. For regional shopping centers comparable in size to the Liberty Tree Mall, the trip generation range given in the GEOMET report[2] and based on Washington, D.C. data,[6] is given as 10 to 25 per 1000 square feet per average day and the median value is 18 per 1000 square feet. At the time of the selection of the Liberty Tree Mall for this study, estimates of trip generation were not available. However, traffic volume counts made during the program, when adjusted on the basis of seasonal parking demands and traffic counts at shopping centers,[7] indicate a one-way trip generation rate for an average weekday of approximately 22 trips per 1,000 square feet of gross leasible floor space.

From the above description, it can be seen that the Liberty Tree Mall not only qualifies as a regional shopping center, but also lies about midway in both size and trip generating ability between the lower and upper limits of such centers.

In addition to qualifying as a representative regional shopping center, the Liberty Tree Mall is suitably located for traffic and air quality monitoring studies. The collection of definitive traffic data is facilitated by the layout of access roads and by the limited number of gates. Also, the existence of both signalized and non-signalized gates offers the possibility of analyzing two separate traffic management schemes. Being upwind of the only major nearby highway (Route 128) during prevailing westerly winds, the shopping center is generally free from significant contributions of carbon monoxide from confounding sources. Further, the terrain in the immediate vicinity of the center is relatively smooth other than an embankment at Route 128 and a low hill across Route 123 from the center. Route 128 is a circumferential highway around Boston and carries about 38,000 vehicles per day on the section near the Liberty Tree Mall. Land in the vicinity of the center is primarily devoted to residential and small business use, broken by wooded areas and fields.

## SECTION IV

## MONITORING PROGRAM

The field measurement program was carried out at the Liberty Tree Shopping Center from December 10, 1973 through December 24, 1973 to measure conditions during the peak shopping period of the year. Figure 2 is a plan of the shopping center showing the principal features of the center and the monitoring networks. Details of the monitoring networks and instrumentation follow.

### TRAFFIC VOLUME COUNTS

Automatic traffic recorder (ATR) counts were taken at 11 locations at and adjacent to the Liberty Tree Mall. ATR's were placed at each of the four entrance/exit roadways (gates A, B, C, and D shown in Figure 2) to determine directional traffic volumes into and out of the shopping center. The remaining ATR's were located on three roadways adjacent to the center, and measured the two-way traffic volumes passing each of the four gates.

The ATR's were battery operated and impulse actuated. Time was kept by either a mechanical or electrical timepiece that advanced the recording tapes at 15-minute intervals.

The ATR's were put in place on Sunday, December 9, 1973, and operated continuously until 2300 EST on Sunday, December 15, 1973. At this time, they were shut down and the rubber hoses taken off and stored because of an approaching major snow and ice storm. Due to this storm, field

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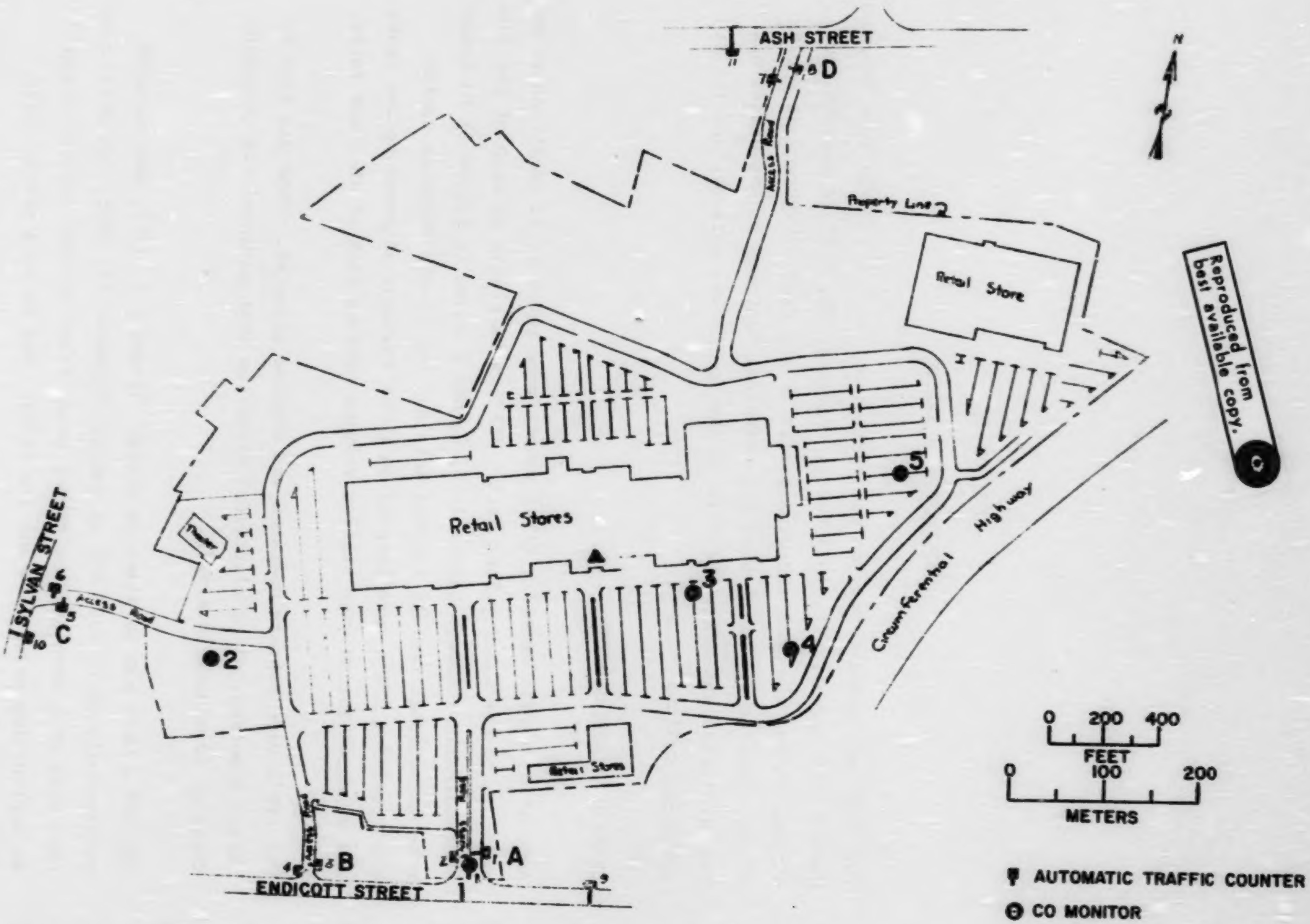
ASH STREET
D
7
8
N
Access Road
Property Line
Retail Store
Retail Stores
Retail Stores
5
3
4
2
SYLVAN STREET
Access Road
C
5
6
10
B
4
A
1
2
9
ENDICOTT STREET
Circumferential Highway
0 200 400
FEET
0 100 200
METERS
AUTOMATIC TRAFFIC COUNTER
CO MONITOR
WIND SPEED & DIRECTION

Figure 2. Sketch showing principal features of Liberty Tree Mall and the location of monitoring devices

Reproduced from best available copy.

operations were cancelled on Monday, December 17th and the ATR's were not reactivated until the morning of the following day. The machines then operated continuously throughout the balance of the program.

All ATR's were checked at least twice a day. With the exception of the counter measuring outbound flow at gate C (ATR number 6), which experienced vandalism and numerous operational problems, the stations were relatively trouble free.

## RUNNING TIMES

Three 2-man crews (driver and recorder) observed traffic conditions and gathered the necessary data for the calculation of average running times and trip lengths during the program. The observation period began at 1000 EST each morning and continued until the close of the principal businesses at the end of the day.

The method used by the field crews to gather the necessary data was as follows:

1. At the start of a work period, study cars were chosen at each gate at random. This was done by queuing up at an entrance and following the car immediately ahead of the observer.
2. The period of observation began when the study car entered the shopping center through the gate and ended when the study car had been parked and its engine had been turned off.
3. A nearby departing vehicle (preferably just starting up) was selected as the next study vehicle and followed until it passed through an exit gate.
4. The field crew then left the shopping center, reentered at the same gate, and repeated the observing cycle.

Each study car was classified by gate, and as an arrival or a departure. Supplemental information collected included the parking location of each study car.

## METEOROLOGICAL DATA

Wind speed and wind direction measurements were made by a Climatronics Mark III wind system mounted on an 18-foot mast located on the mall roof as shown in Figure 2. Wind data were recorded continuously on chart rolls and averaged visually over one-hour periods.

Consideration was given to the installation of a wind system within the parking lot to obtain low-level turbulence measurements for use as direct indicators of diffusion rates in model calculations. This approach was abandoned in favor of the roof-top installation, however, because of the fear of possible interference by passersby or of vandalism.

## CARBON MONOXIDE CONCENTRATIONS

Carbon monoxide concentrations were measured from about 1000-2230 EST each day at the five locations shown in Figure 2. Each installation consisted of a wooden shelter, secured at an elevation of approximately two meters above grade, which housed the carbon monoxide detector, strip chart recorder, and a heater. The instruments were collected each night at the end of the day's operation.

The carbon monoxide detector used was the Ecolyzer model 2600 equipped with a model 2115 recorder. Although this detector lacks the reliability and accuracy of an NDIR instrument, it is convenient for field use because of its portability, and it has the added advantage of optional battery operation. This instrument has a dual range, 0-50 ppm and 0-100 ppm; with few exceptions, the more sensitive range was used throughout the program.

Electrical power was available at Stations 1, 2, and 4 and the instruments and heaters at these locations were run on alternating current. Lack of power at Stations 3 and 5 necessitated running the carbon monoxide monitors and recorders on the built-in nickel cadmium batteries. The heat for the instruments shelters at these locations was supplied by resistors which drew current from 12-volt wet storage batteries.

Early in the sampling program it became apparent that the nickel cadmium batteries in the Ecolyzers could not supply enough power to run the instrument and recorder for a full sampling day. The four C cells, which supply the electronics and recorder, would last about seven hours. The single D cell, however, which powers the sampling pump, would last only 3-4 hours. To minimize the amount of down time required for changing batteries and also reduce the number of times the shelters had to be opened and the instrument exposed to the cold ambient temperatures, a 1.5 volt dry cell was placed in parallel with the D cell. This arrangement eliminated the need to change the D cell during the sampling day.

Each instrument was calibrated at the beginning of each day when being installed, once about midway through the day, and again at the end of the day when the instrument was being taken in for the night. During the first week of the field program each calibration consisted of first zeroing the instrument and then introducing a carbon monoxide concentration of 44.5 ppm. During the second week additional calibration gases were available and each instrument was zeroed and then 5, 21, and 38 ppm carbon monoxide introduced in sequence. A best fit curve was drawn for each calibration and a linear extrapolation between calibrations was used whenever a change in the calibration occurred.

Observations were made successfully approximately 91 percent of the time when the instruments were on alternating current, but only 64 percent of the time during battery operation.

It should be noted that the Ecolyzer is not a Federal reference method for carbon monoxide, and the observations reported here should be interpreted accordingly. In field use, the instruments were found to be sensitive to changes in temperature. However, care was taken to minimize errors resulting from this or other causes by procedures discussed in the preceding paragraphs, including frequent checks on instrument calibration.

# SECTION V

## SUMMARY OF FIELD DATA

### TRAFFIC VOLUMES

Traffic count data from the 11 ATR's are tabulated in Appendix A. Table A-1 presents the data by gate (in and out) for each hour from 0800 until 2300 EST except for Monday, December 24th, when the shopping center closed at 1800 EST. Table A-2 presents the two-way counts observed on the three adjacent roadways.

This section summarizes the overall traffic flow during the period. More detail is given in the following section on running times and in Section VI where traffic data is used in evaluating the methodology for impact assessment.

Table 1 gives the total volume of one-way traffic by day and the peak hour traffic both by vehicle count and as the percent of the day's traffic. The average weekday volume during this pre-Christmas period was 49,966; the average Saturday volume was 64,471. The average peak hour volume was 9.7 and 9.5 percent respectively of the weekday and Saturday total volumes.

The average variation in traffic throughout the day is shown in Figure 3 for weekdays and Saturdays. In each part of the figure, the upper curve shows the average variation of traffic through all gates, and the lower curve shows the variation of traffic through the main gate (Gate A). The total peak hour traffic through all gates occurs between 1900-2000 EST on weekdays and between 1400-1500 EST on Saturdays.

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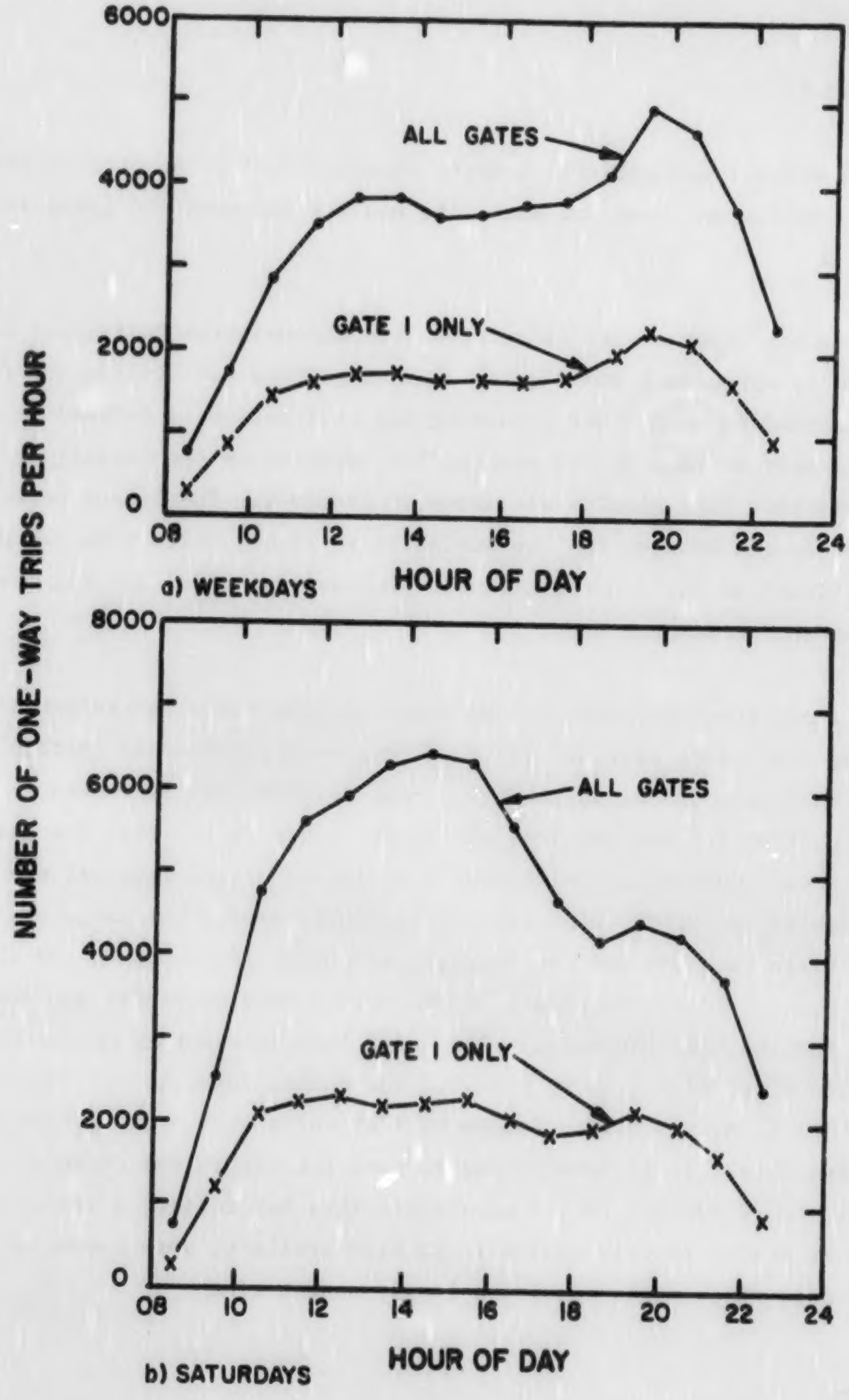
Table 1. DAILY AND PEAK HOUR TRAFFIC VOLUMES AT THE LIBERTY TREE SHOPPING CENTER

| Date | Day of week | Total volume[a] | Peak hour volume[b] | |
|---|---|---|---|---|
| | | | No. veh. | % of total |
| 12/10 | Mon. | 49,387 | 4890 | 9.9 |
| 12/11 | Tues. | 44,982 | 4434 | 9.9 |
| 12/12 | Wed. | 45,008 | 4356 | 9.7 |
| 12/13 | Thurs. | 45,828 | 4696 | 10.2 |
| 12/14 | Fri. | 44,933 | 4714 | 10.5 |
| 12/15 | Sat. | 60,810 | 5713 | 9.4 |
| 12/18 | Tues. | 52,371 | 5005 | 9.6 |
| 12/19 | Wed. | 54,965 | 5207 | 9.5 |
| 12/20 | Thurs. | 54,746 | 5119 | 9.4 |
| 12/21 | Fri. | 57,474 | 5210 | 9.1 |
| 12/22 | Sat. | 68,132 | 6492 | 9.5 |
| 12/24 | Mon. | 46,770 | 6449 | 13.8 |
| Average weekday | | 49,966 | 4848 | 9.7 |
| Average Saturday | | 64,471 | 6102 | 9.5 |

[a] Total traffic count, in plus out.

[b] Weekday peak 1900 - 2000 EST
Saturday peak 1400 - 1500 EST
Monday (12/24) 1400 - 1500 EST



a) WEEKDAYS

b) SATURDAYS

Figure 3. Average hourly variation in traffic at Liberty Tree Mall.

## RUNNING TIMES

Average running times and trip lengths observed during the program are tabulated by day and hour for each gate and for the combined gates in Appendix B.

Average vehicle speeds were calculated from the weighted "all-gate" values presented in Appendix B and plotted against parking lot utilization for the corresponding hour. Here, parking lot utilization is defined as the average number of cars in the parking lot, divided by the capacity of the lot, times 100. The results are shown in Figure 4. The linear correlation coefficient between the two variables is -0.48, which with 140 pairs, is significant at the 1 percent level. The average speed for all observations was 10.7 miles per hour.

Running times representative of the whole parking lot were estimated by weighting the values obtained for each gate by the volume of traffic through that gate during that hour. These weighted hourly values, plotted against parking lot utilization, are shown in Figure 5. They are also tabulated in Appendix C. The linear correlation coefficient between these two variables is +0.59. When the lot is nearly empty, the range of running times is small and the average is roughly 100 seconds. As the lot becomes more crowded, the points become more widely scattered and the average running time increases. The solid line in Figure 5 is the linear regression line, RT = 1.59 PC + 62.9. The dashed curve in the figure has been fitted to median values (shown by X's) calculated over appropriate class intervals. It is interesting to note the dip in the curve as the lot fills to 70 percent of its capacity. This may reflect a tendency for drivers to prefer readily available parking stalls to more conveniently located ones which might require a longer search time.

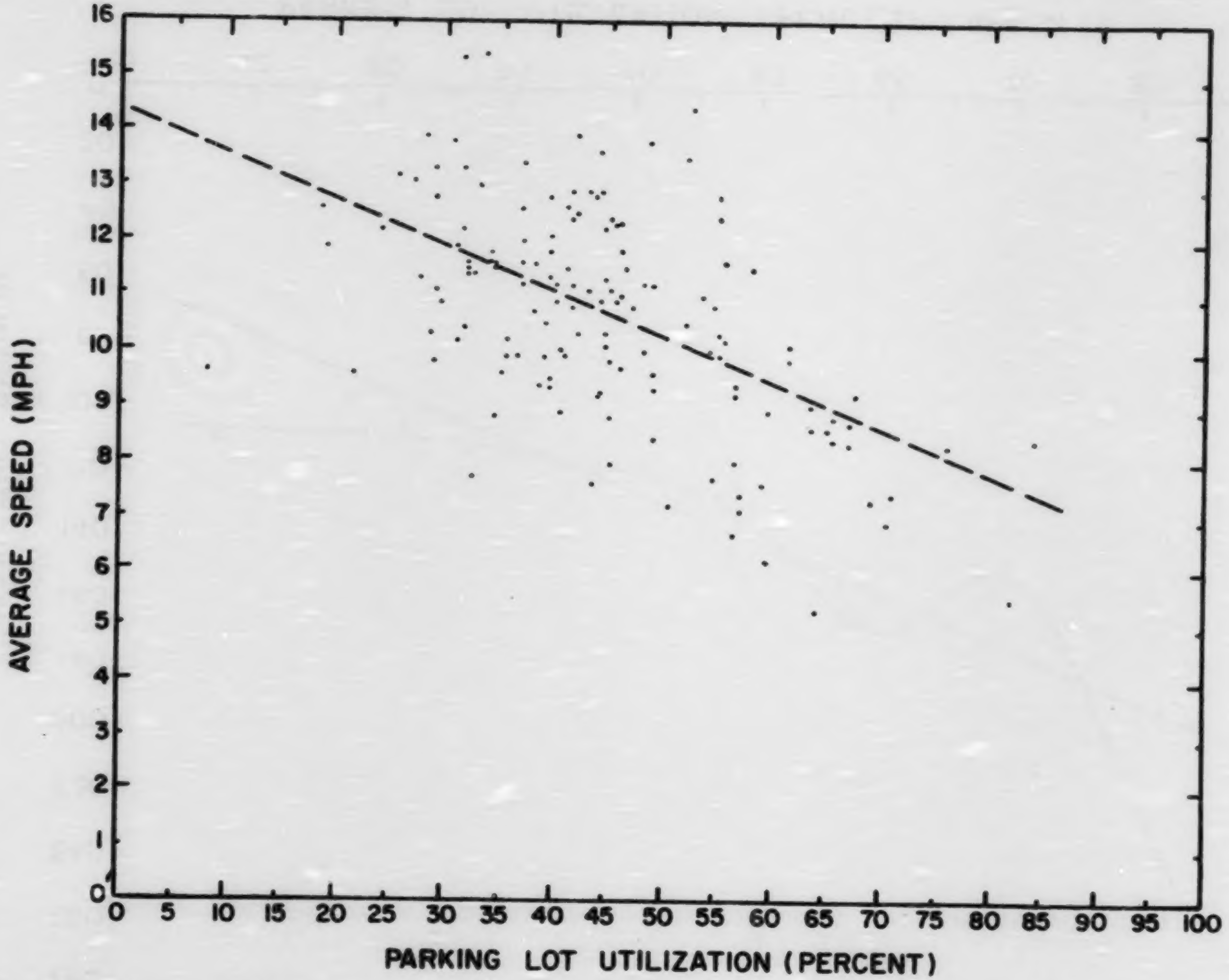


Figure 4. Average vehicle speed at Liberty Tree Shopping Center as a function of parking lot utilization

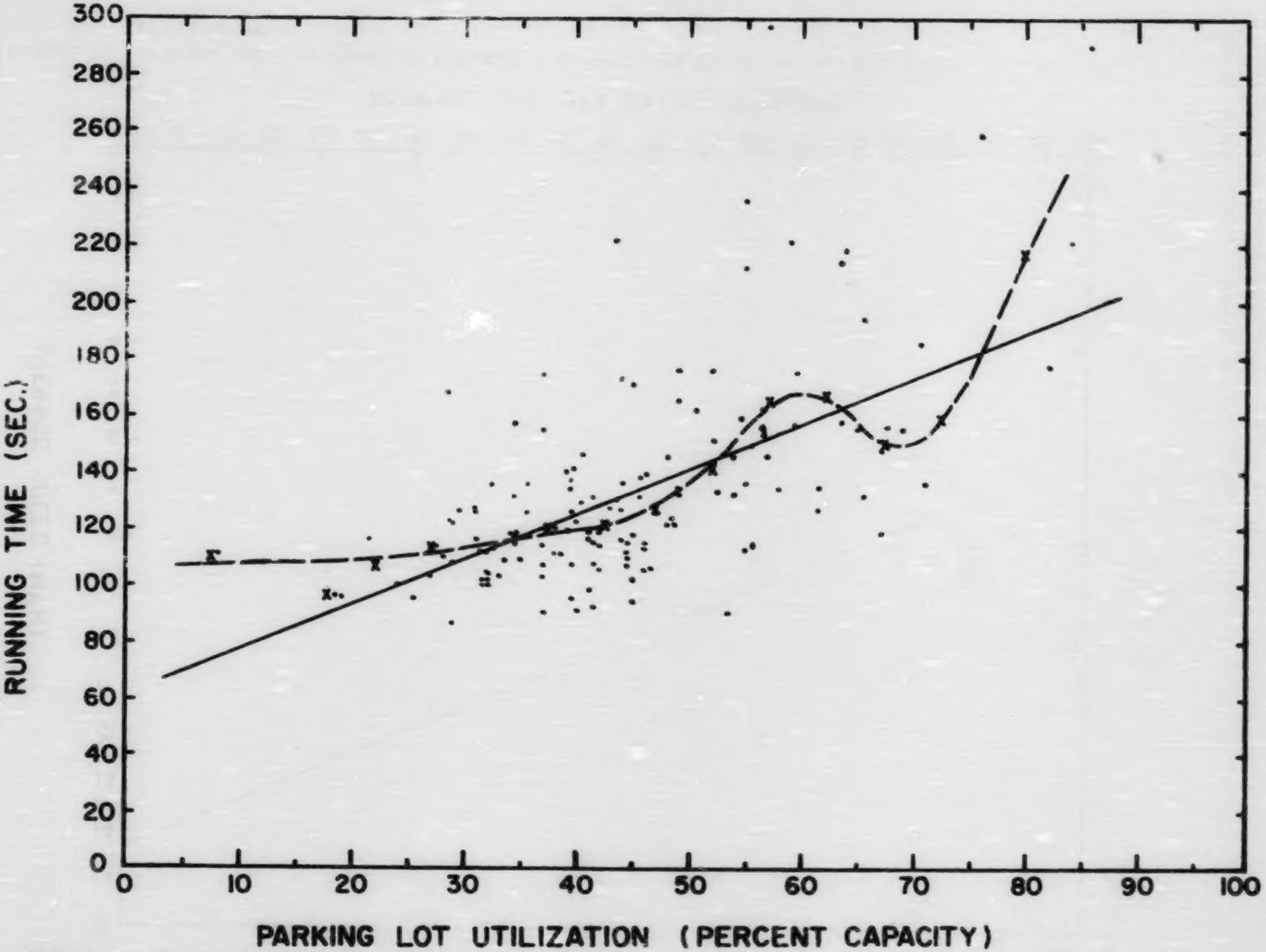


Figure 5. Base running time at Liberty Tree Shopping Center as a function of parking lot utilization

## METEOROLOGICAL CONDITIONS

A severe storm, beginning as snow and freezing rain on Sunday, December 16, 1973, prevented the collection of field data on Monday, December 17th. With this exception, it was possible to make both traffic and carbon monoxide measurements on all days of the scheduled sampling program, although cold temperatures occasionally prevented satisfactory operation of the battery powered Ecolyzers.

During the 12 days when field data were collected the prevailing wind direction was west-northwest, so that the shopping center was largely free of significant interferences from traffic emissions on Route 128. Frequency distributions of wind direction and wind speed for the period 0800-2300 EST on observation days are given in Table 2.

A summary of meteorological conditions, including stability classification, by hour is presented in Appendix E.

## CARBON MONOXIDE CONCENTRATIONS

One-hour average carbon monoxide concentrations are tabulated by station location in Appendix F. This section presents frequency distributions and statistics for these 1-hour values and for calculated 8-hour averages, and the average weekday and Saturday diurnal variations in concentrations.

Table 3 includes two frequency distributions for 1-hour concentrations. The one to the left in the table is for Station 1, located at the main gate (Gate A). The distribution to the right is for the remaining four stations. This separation has been made to show the difference in concentration usually experienced between the main gate and locations distributed throughout the adjacent to the parking lot. This difference is further illustrated in Table 4 which gives means and standard deviations of the 1-hour concentrations for each station. The maximum 1-hour

Table 2. FREQUENCY DISTRIBUTION OF WIND DIRECTION AND SPEED DURING MEASUREMENT

| Wind direction | | |
|---|---|---|
| Direction (deg) | No. hours | Percent |
| 0 | 2 | 1.1 |
| 10 | 0 | 0 |
| 20 | 4 | 4 |
| 30 | 1 | 0.6 |
| 40 | 2 | 1.1 |
| 50 | 0 | 0 |
| 60 | 0 | 0 |
| 70 | 0 | 0 |
| 80 | 0 | 0 |
| 90 | 0 | 0 |
| 100 | 0 | 0 |
| 110 | 0 | 0 |
| 120 | 6 | 3.4 |
| 130 | 3 | 1.7 |
| 140 | 8 | 4.5 |
| 150 | 5 | 2.8 |
| 160 | 4 | 2.3 |
| 170 | 8 | 4.5 |
| 180 | 2 | 1.1 |
| 190 | 3 | 1.7 |
| 200 | 0 | 0 |
| 210 | 1 | 0.6 |
| 220 | 0 | 0 |
| 230 | 3 | 1.7 |
| 240 | 2 | 1.1 |
| 250 | 6 | 3.4 |
| 260 | 8 | 4.5 |
| 270 | 9 | 5.1 |
| 280 | 17 | 9.7 |
| 290 | 21 | 11.9 |
| 300 | 18 | 10.2 |
| 310 | 16 | 9.1 |
| 320 | 14 | 8.0 |
| 330 | 6 | 3.4 |
| 340 | 4 | 2.3 |
| 350 | 3 | 1.7 |
| | 176 | 99.8 |

| Wind speed | | |
|---|---|---|
| Speed (m/sec) | No. hours | Percent |
| 0.0- 0.9 | 2 | 1.1 |
| 1.0- 1.9 | 34 | 19.3 |
| 2.0- 2.9 | 45 | 25.6 |
| 3.0- 3.9 | 27 | 15.3 |
| 4.0- 4.9 | 29 | 16.5 |
| 5.0- 5.9 | 7 | 4.0 |
| 6.0- 6.9 | 17 | 9.6 |
| 7.0- 7.9 | 10 | 5.7 |
| 8.0- 8.9 | 4 | 2.3 |
| 9.0- 9.9 | 0 | 0 |
| 10.0-10.9 | 1 | 0.6 |
| | 176 | 100.0 |

Table 3. FREQUENCY DISTRIBUTION OF 1-HOUR CO CONCENTRATIONS AT LIBERTY TREE MALL

| Class interval (ppm) | Station 1 | | | Stations 2, 3, 4, 5 | | |
|---|---|---|---|---|---|---|
| | Number of observations | Percent of sample | Cumulative percent | Number of observations | Percent of sample | Cumulative percent |
| 0- 0.9 | 1 | 0.78 | 0.78 | 81 | 18.53 | 18.53 |
| 1- 1.9 | 13 | 10.16 | 10.94 | 134 | 30.66 | 49.19 |
| 2- 2.9 | 17 | 13.28 | 24.22 | 108 | 24.71 | 73.90 |
| 3- 3.9 | 14 | 10.94 | 35.16 | 63 | 14.42 | 88.32 |
| 4- 4.9 | 12 | 9.38 | 44.54 | 24 | 5.49 | 93.81 |
| 5- 5.9 | 6 | 4.69 | 49.23 | 8 | 1.83 | 95.64 |
| 6- 6.9 | 17 | 13.28 | 62.51 | 8 | 1.83 | 97.47 |
| 7- 7.9 | 13 | 10.16 | 62.67 | 3 | 0.69 | 98.16 |
| 8- 8.9 | 9 | 7.03 | 79.70 | 3 | 0.69 | 98.85 |
| 9- 9.9 | 3 | 2.34 | 82.04 | 0 | 0 | 98.85 |
| 10-10.9 | 4 | 3.13 | 85.17 | 2 | 0.46 | 99.31 |
| 11-11.9 | 3 | 2.34 | 87.51 | 1 | 0.23 | 99.54 |
| 12-12.9 | 3 | 2.34 | 89.85 | 2 | 0.46 | 100.00 |
| 13-13.9 | 0 | 0 | 89.85 | | | |
| 14-14.9 | 3 | 2.34 | 92.19 | | | |
| 15-15.9 | 0 | 0 | 92.19 | | | |
| 16-16.9 | 0 | 0 | 92.19 | | | |
| 17-17.9 | 2 | 1.56 | 93.75 | | | |
| 18-18.9 | 0 | 0 | 93.75 | | | |
| 19-19.9 | 1 | 0.78 | 94.53 | | | |
| 20-20.9 | 1 | 0.78 | 95.31 | | | |
| 21-21.9 | 2 | 1.56 | 96.87 | | | |
| 22-22.9 | 0 | 0 | 96.87 | | | |
| 23-23.9 | 1 | 0.78 | 97.65 | | | |
| 24-24.9 | 1 | 0.78 | 98.43 | | | |
| 25-25.9 | 1 | 0.78 | 99.21 | | | |
| 26-26.9 | 0 | 0 | 99.21 | | | |
| 27-27.9 | 0 | 0 | 99.21 | | | |
| 28-28.9 | 0 | 0 | 99.21 | | | |
| 29-29.9 | 0 | 0 | 99.21 | | | |
| 30-30.9 | 1 | 0.78 | 99.99 | | | |
| TOTAL | 128 | 99.99 | | 437 | 100.00 | |

Table 4. STATISTICAL SUMMARY OF 1-HOUR CO CONCENTRATIONS (PPM) OBSERVED DURING FIELD PROGRAM

| | Station | | | | |
|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 |
| N | 128 | 122 | 91 | 133 | 91 |
| Mean | | | | | |
| Arithmetic | 6.86 | 1.97 | 2.48 | 2.91 | 1.77 |
| Geometric | 5.16 | 1.39 | 1.99 | 2.48 | 1.44 |
| Standard Deviation | | | | | |
| Arithmetic | 5.48 | 1.94 | 1.74 | 1.84 | 1.11 |
| Geometric | 1.38 | 1.39 | 1.27 | 1.18 | 1.27 |
| Maximum | 30.6 | 10.6 | 12.8 | 12.6 | 7.6 |

concentration at Station 1 was 30.6 ppm, slightly below the 1-hour national standard of 35 ppm. The highest value at any of the remaining stations was 12.8 ppm.

Table 5 shows frequency distributions of 8-hour average carbon monoxide concentrations, again calculated for the two station groupings. The observed concentrations are well below the national 8-hour standard of 9 ppm at Stations 2, 3, 4, and 5. On the other hand, approximately 32 percent of the 8-hour observations (based on running means) equaled or exceeded the standard at Station 1.

Table 6 lists the maximum 8-hour and 1-hour concentrations observed each day at each of the five stations, and the corresponding calculated ratio of these maximum values. These ratios incorporate the integrated effects of traffic and meteorological variations during an 8-hour period. As noted at the bottom of the table, the arithmetic mean of these ratios is 0.58 and the geometric mean of the ratios is 0.55. A discussion is presented in Section VI of possible causes of the variability denoted by this ratio, based on examination of the distance scales involved, wind variations, and traffic fluctuations over an 8-hour period.

Figure 6 shows the average diurnal variation in carbon monoxide concentration for weekdays and for Saturdays as observed at Station 1 and at the four other monitoring locations.

Table 5. FREQUENCY DISTRIBUTION OF 8-HOUR[a] CO CONCENTRATIONS AT LIBERTY TREE MALL

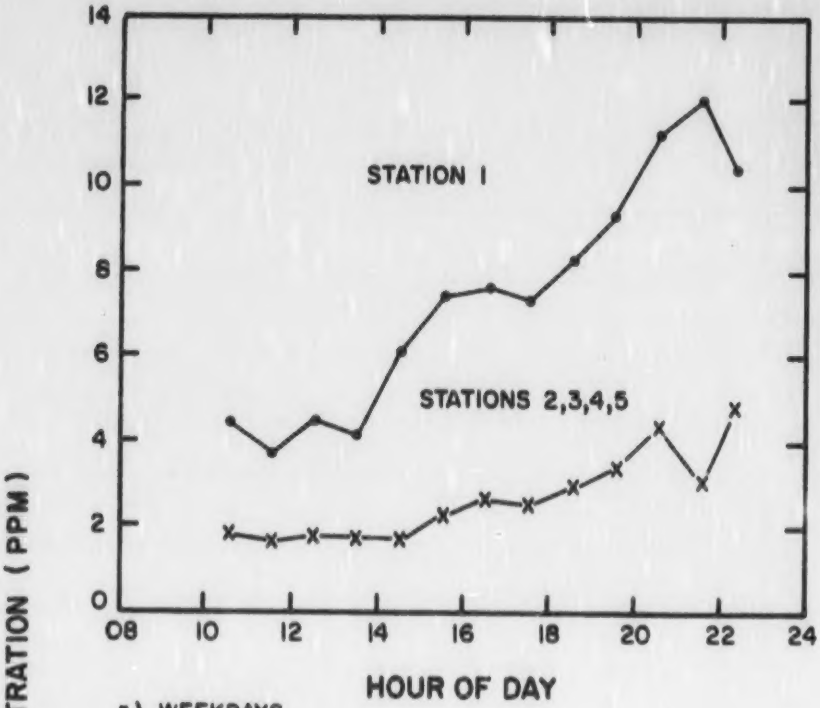
| | Station 1 | | | Stations 2, 3, 4, 5 | | |
|---|---|---|---|---|---|---|
| Interval | Number of observations | Percent of sample | Cumulative percent | Number of observations | Percent of sample | Cumulative percent |
| 0- 0.9 | 0 | 0 | 0 | 6 | 4.17 | 4.17 |
| 1- 1.9 | 3 | 6.82 | 6.82 | 42 | 29.17 | 33.34 |
| 2- 2.9 | 1 | 2.27 | 9.09 | 57 | 39.58 | 72.92 |
| 3- 3.9 | 7 | 15.91 | 25.00 | 26 | 18.06 | 90.98 |
| 4- 4.9 | 5 | 11.36 | 36.36 | 12 | 8.33 | 99.31 |
| 5- 5.9 | 1 | 2.27 | 38.63 | 1 | 0.69 | 100.00 |
| 6- 6.9 | 2 | 4.55 | 43.18 | | | |
| 7- 7.9 | 3 | 6.82 | 50.00 | | | |
| 8- 8.9 | 8 | 18.18 | 68.18 | | | |
| 9- 9.9 | 8 | 18.18 | 86.36 | | | |
| 10-10.9 | 2 | 4.55 | 90.91 | | | |
| 11-11.9 | 0 | 0 | 90.91 | | | |
| 12-12.9 | 4 | 9.09 | 100.00 | | | |
| TOTAL | 44 | 100.00 | | 144 | 100.00 | 100.00 |

[a] 8-hour concentrations are based on running means to the extent limited sampling periods permit.

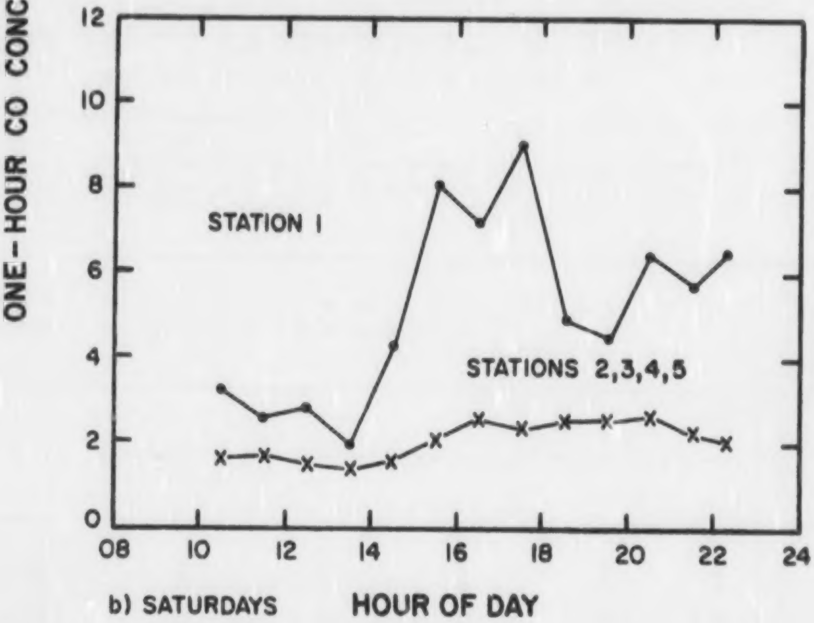
Table 6. MAXIMUM 8-HOUR AND 1-HOUR CO CONCENTRATIONS OBSERVED EACH DAY AND ASSOCIATED 8-HOUR/1-HOUR RATIOS

| Date | Sampler | Concentration (ppm) |  | 8-hr/1-hr | Date | Sampler | Concentration (ppm) |  | 8-hr/1-hr |
|---|---|---|---|---|---|---|---|---|---|
|  |  | Max 8-hr | Max 1-hr |  |  |  | Max 8-hr | Max 1-hr |  |
| 10 Dec. | 1 | 12.7 | 24.7 | 0.51 | 18 Dec. | 1 | 2.7 | 8.0 | 0.34 |
|  | 2 | 4.4 | 8.5 | 0.52 |  | 2 | 1.0 | 1.2 | 0.83 |
|  | 3 | - | 1.6 | - |  | 3 | - | - | - |
|  | 4 | 4.6 | 7.2 | 0.64 |  | 4 | 2.8 | 4.0 | 0.70 |
|  | 5 | - | 4.4 | - |  | 5 | - | - | - |
| 11 Dec. | 1 | 4.6 | 8.8 | 0.52 | 19 Dec. | 1 | 12.1 | 20.5 | 0.59 |
|  | 2 | 1.4 | 2.2 | 0.64 |  | 2 | 1.7 | 2.8 | 0.61 |
|  | 3 | - | - | - |  | 3 | 1.4 | 2.4 | 0.58 |
|  | 4 | 2.8 | 4.2 | 0.67 |  | 4 | 2.6 | 4.5 | 0.58 |
|  | 5 | - | 0.9 | - |  | 5 | 2.7 | 3.1 | 0.87 |
| 12 Dec. | 1 | 8.5 | 25.0 | 0.34 | 20 Dec. | 1 | 12.2 | 30.6 | 0.40 |
|  | 2 | 3.3 | 6.2 | 0.53 |  | 2 | 3.6 | 8.8 | 0.41 |
|  | 3 | 3.2 | 6.5 | 0.49 |  | 3 | 4.7 | 12.8 | 0.37 |
|  | 4 | 4.1 | 6.9 | 0.59 |  | 4 | 5.4 | 12.6 | 0.43 |
|  | 5 | 2.4 | 4.6 | 0.52 |  | 5 | 2.6 | 7.6 | 0.34 |
| 13 Dec. | 1 | 8.6 | 11.4 | 0.75 | 21 Dec. | 1 | - | 7.2 | - |
|  | 2 | 2.7 | 4.1 | 0.65 |  | 2 | - | 1.9 | - |
|  | 3 | 3.5 | 4.8 | 0.73 |  | 3 | 2.8 | 4.2 | 0.67 |
|  | 4 | 3.2 | 4.2 | 0.76 |  | 4 | 1.9 | 2.9 | 0.66 |
|  | 5 | 2.6 | 3.5 | 0.74 |  | 5 | 1.4 | 1.8 | 0.78 |
| 14 Dec. | 1 | 9.6 | 23.0 | 0.42 | 22 Dec. | 1 | 4.1 | 7.0 | 0.59 |
|  | 2 | 3.7 | 10.6 | 0.35 |  | 2 | 1.0 | 2.5 | 0.40 |
|  | 3 | - | 1.0 | - |  | 3 | 3.2 | 4.8 | 0.67 |
|  | 4 | 4.6 | 11.6 | 0.40 |  | 4 | 2.4 | 3.8 | 0.63 |
|  | 5 | - | - | - |  | 5 | 2.0 | 2.7 | 0.74 |
| 15 Dec. | 1 | 8.5 | 12.1 | 0.70 | 24 Dec. | 1 | 7.0 | 10.8 | 0.65 |
|  | 2 | 1.2 | 1.9 | 0.63 |  | 2 | 0.8 | 2.0 | 0.40 |
|  | 3 | 2.6 | 4.3 | 0.60 |  | 3 | - | 1.2 | - |
|  | 4 | 3.3 | 3.8 | 0.87 |  | 4 | - | 1.8 | - |
|  | 5 | - | 2.0 | - |  | 5 | - | 0.8 | - |

Maximum 8-hr conc. during period - 12.7 ppm
Maximum 1-hr conc. during period - 30.6 ppm
Range of 8-hr/1-hr ratio - 0.34-0.87
Arith. mean of ratios - 0.58
Geom. mean of ratios - 0.55



a) WEEKDAYS



b) SATURDAYS

Figure 6. Average diurnal variation of carbon monoxide concentration at Liberty Tree Mall

# SECTION VI

## VALIDATION OF THE PROPOSED METHODOLOGY

### INTRODUCTION

This section presents the comparisons of observed and calculated carbon monoxide concentrations for peak 1- and 8-hour periods. Calculated values for 1-hour periods are found (1) by using the proposed methodology entirely, and (2) by using measured input parameters in the proposed scheme when possible. Values for 8-hour periods are calculated by the proposed methodology only.

The proposed methodology assumes that peak traffic volumes occur between 8 and 9 p.m. on weekdays and 3 and 4 p.m. on Saturday. Traffic at Liberty Tree Mall was observed to reach a peak 1 hour earlier than these assumed times. Comparisons of calculated and observed concentrations for the actual peak traffic hour are of most interest, regardless of when this hour occurs, since the purpose of this preliminary methodology is to estimate maximum carbon monoxide concentrations. Two sets of comparisons are made for 1-hour periods: (1) those for the stated peak traffic hour, and (2) those for the observed peak traffic hour. For the stated peak hour, the correlation between observed and calculated values is 0.14 when the methodology is used entirely, and 0.30 using measured input values. For the observed peak hour, however, the correlations are 0.53 using the methodology and 0.56 using measured inputs. These latter correlations represent significance at about the 10 percent level. The correlation between 8-hour values calculated by the proposed methodology and observed values in -0.15.

Also presented in this section are comparisons of traffic volume estimation parameters given in the proposed methodology and those measured at the Liberty Tree Mall. The peak measured traffic volumes are higher than those estimated using the proposed methodology; however, the average daily trip generation equals the mean and median value found for shopping centers of the same general size.

A discussion is given of likely sources of error in the methodology. The possible modification of calculating concentrations from volume/capacity ratios at gates is analyzed for peak exit volumes. A correlation of 0.83 is found, representing significance greater than the 1-percent level, but a correlation of concentration and inverse wind speed alone yields $r = 0.86$.

## COMPARISON OF OBSERVED AND CALCULATED CONCENTRATIONS

The Liberty Tree Mall has 867,000 square feet of gross leasible floor space. According to the proposed methodology the "average day" round trip generation rates for a center of this size are from 10 to 25 trips per 1,000 square feet of gross leasible floor space, with the mean and median values both equal to 18. Liberty Tree Mall was found to generate 31 trips during the study period. Dividing this by the December adjustment factor[2] of 1.4 yields 22 average day round trips per 1,000 square feet of gross leasible floor space. This falls within the range identified in reference 2. A value of 18 was chosen for the subsequent analysis, however, since this is the value one might pick for evaluating a proposed shopping center of similar size.

The average daily trips are thus calculated as

$$\text{ADT} = \frac{(18)\ (867{,}000)}{1{,}000} = 15{,}606 \text{ round trips.} \qquad (9)$$

For the weekday peak hour during December the volume is[1,2]

$$4.3 \times 10^{-5} \text{ ADT} \qquad (10)$$

or

$$(4.3 \times 10^{-5})(15{,}606) = 0.67 \text{ veh/sec.}$$

For the 1-hour peak the methodology assumes that one half of the vehicles are trying to exit. This agrees favorably with measured volumes, which show that an average of 42% of the peak-hour traffic is exiting. Since the calculated volume is for round trips, assuming that one half of the volume is exiting leads to the same value of 0.67 veh/sec exiting (or entering).

The exit gate capacities, $g_i$, are from Appendix D:

| | |
|---|---|
| Gate A | 0.32 veh/sec, |
| Gate B | 0.23 veh/sec, |
| Gate C | 0.17 veh/sec, |
| and Gate D | 0.29 veh/sec. |

The distribution of use among the gates is calculated from Appendix A:

| | |
|---|---|
| Gate A | 40 percent, |
| Gate B | 26 percent, |
| Gate C | 17 percent, |
| and Gate D | 17 percent. |

The value of the utilization factor, a, equals the traffic flow divided by the gate capacity. Hence for Gate A,

$$a = \frac{(0.67 \text{ veh/sec})(0.40 \text{ fraction of traffic using Gate A})}{(0.32 \text{ veh/sec})} \qquad (11)$$

$$= 0.84$$

For the other gates a is found to be:

| | |
|---|---|
| Gate B | a = 0.76 |
| Gate C | a = 0.67 |
| and Gate D | a = 0.39 |

The average value of a is 0.67 and b, the inverse of average gate capacity, is 3.96.

Gates A, B, and C are signalized, with an average red phase of 58 seconds. These gates carry 83 percent of the exiting traffic, so

$$C = (0.5)(58)(0.83) \tag{12}$$

$$= 24 \text{ seconds.}$$

The running time given by equation (5) is then

$$RT = 270 + (3.96)(0.67/1 - 0.67) + 24 \tag{13}$$

$$= 302$$

(where 270 seconds is the average base running time provided by the methodology).

The emission factor for a 1973 mix of vehicles is computed from the 1974 value of 16.2 g/min as

$$ef = 16.2\ (62/56) \tag{14}$$

$$= 17.9 \text{ g/min,}$$

where 62 and 56 are the grams per mile for 1973 and 1974 vehicle mixes, respectively.

The parking and mall area for the complex is $2.64 \times 10^5$ square meters, so the emission density is, by equation (2):

$$Q = \frac{(17.9)(0.67)(302)}{(60)(2.64 \times 10^5)} \tag{15}$$

$$= 2.3 \times 10^{-4} \text{ g/m}^2 - \text{sec}$$

For the peak Saturday hour the volume is $6.7 \times 10^{-5}$ ADT, and the emission density found by the same procedure as shown for weekdays is

$$Q = \frac{(17.9)(1.05)(371)}{(60)(2.64 \times 10^5)}$$

$$= 4.4 \times 10^{-4} \text{ g/m}^2 - \text{sec}$$

Table 7 summarizes the parameters used to estimate the 1- and 8-hour weekday and Saturday area source emission strengths by the proposed methodology.

Figure 7 shows the curves of concentration versus distance for the calculated area source strengths, D stability, and 1 m/sec wind speed.

Emission densities for each peak hour period were also calculated from measured hourly traffic volumes and the average running time for a trip into or out of the shopping center. For this case,

$$Q = \frac{(V/3600)(RT)(17.9)}{(60)(2.64 \times 10^5)} \tag{16}$$

Concentrations were found using the area source curves of the methodology and assuming a stability one class less stable than that observed.

Table 8 and Figure 8 display comparisons of these calculated concentrations with those observed. $\chi_{INP}$ denotes concentrations found using measured

### Table 7. SUMMARY OF FACTORS USED TO CALCULATE AREA SOURCE EMISSION STRENGTH

| | |
|---|---|
| Gross leasible floor space | 867,000 |
| Average trip generation | 18 trips/1000 $ft^2$ |
| Average daily traffic | 15,606 round trips |
| Emission factor, 1973 mix | 17.9 g/min |
| Area source size | $2.64 \times 10^5$ $m^2$ |

| | Traffic volume (veh/sec) |
|---|---|
| Weekday peak 1 hour | 0.67 |
| Saturday peak 1 hour | 1.05 |
| Weekday peak 8 hours | 0.53 |
| Saturday peak 8 hours | 0.70 |

| | Gate A | Gate B | Gate C | Gate D |
|---|---|---|---|---|
| Exit capacities (veh/sec) | 0.32 | 0.23 | 0.17 | 0.29 |
| Distribution of use (%) | 40 | 26 | 17 | 17 |

Average outflow time per vehicle, b 3.94 sec

It is assumed that one-half the vehicles are trying to exit.

| | Average utilization factor, a | Running time (sec) | Source strength Q (g/$m^2$ - sec) |
|---|---|---|---|
| Weekday peak 1 hour | 0.66 | 302 | $2.3 \times 10^{-4}$ |
| Saturday peak 1 hour | 1.00 | 371 | $4.4 \times 10^{-4}$ |
| Weekday peak 8 hours | 0.51 | 298 | $1.8 \times 10^{-4}$ |
| Saturday peak 8 hours | 0.67 | 302 | $2.4 \times 10^{-4}$ |

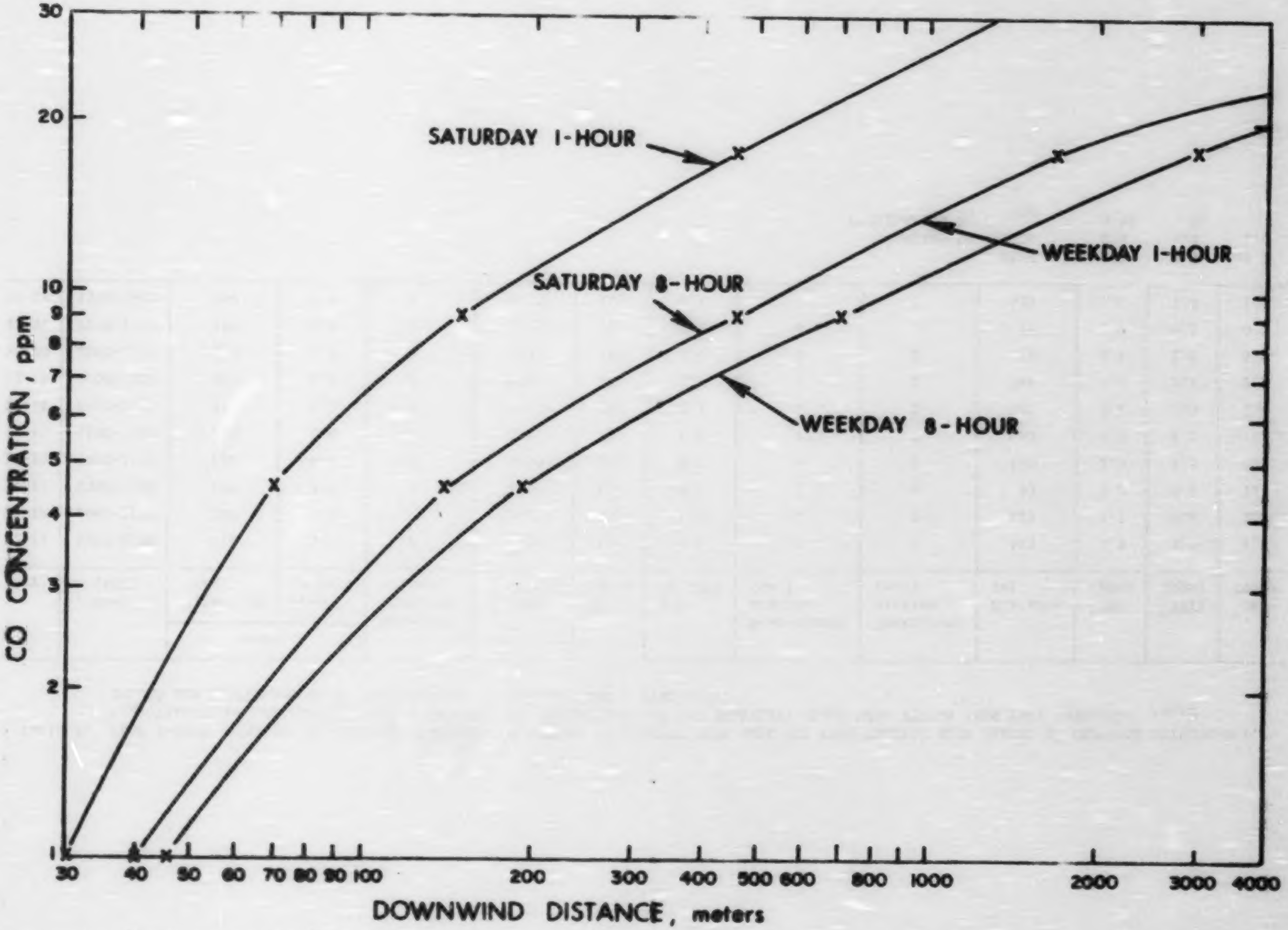


Figure 7. CO concentration as a function of downwind distance for the four calculated emission strengths, D stability, and 1 m/sec wind speed

Table 8. PEAK 1-HOUR OBSERVED AND CALCULATED CO CONCENTRATIONS AT LIBERTY TREE MALL FOR PEAK TRAFFIC HOUR STATED IN PROPOSED METHODOLOGY. $X_{INP}$ VALUES ARE CALCULATED USING MEASURED INPUT PARAMETERS AND ONE STABILITY CLASS LESS STABLE THAN THAT OBSERVED. $X_{METH}$ VALUES ARE CALCULATED USING THE PROPOSED METHODOLOGY AND D STABILITY.

| Day | Hour (EST) | Wind | | Observed stability (class) | Volume (veh/hr) | RT (sec) | Q/U ($\times 10^4$) | Measurement station (no.) | Background station (no.) | Distance (m) | $X_{INP}$ (ppm) | $X_{METH}$ (ppm) | $X_{OBS}$ (ppm) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Direction (deg) | Speed (m/sec) | | | | | | | | | | |
| 12-11 | 2000-2100 | 310 | 3.0 | F | 4286 | 156 | 0.7 | 4 | 2 | 442 | 3.3 | 3.0 | 1.2 |
| 12-12 | 2000-2100 | 300 | 1.0 | F | 3915 | 136 | 1.7 | 4 | 2 | 427 | 7.7 | 8.8 | 2.2 |
| 12-13 | 2000-2100 | 150 | 2.5 | E | 4097 | 134 | 0.7 | 3 | 4 | 92 | 1.0 | 0.9 | 1.1 |
| 12-14 | 2000-2100 | 280 | 4.5 | E | 4450 | 185 | 0.6 | 4 | 2 | 580 | 2.9 | 2.3 | 3.5 |
| 12-15 | 1500-1600 | 310 | 2.0 | D | 5501 | 177 | 1.5 | 4 | 2 | 442 | 4.3 | 8.5 | 2.1 |
| 12-18 | 2000-2100 | 300 | 4.5 | E | 4813 | 194 | 0.7 | 4 | 2 | 427 | 2.7 | 2.0 | 2.8 |
| 12-19 | 2000-2100 | 240 | 1.0 | D | 4953 | 175 | 2.7 | 4 | 2 | 366 | 7.1 | 8.2 | 2.3 |
| 12-20 | 2000-2100 | 190 | 1.0 | F | 4935 | 157 | 2.4 | 4 | 2 | 76 | 2.7 | 1.9 | 3.8 |
| 12-21 | 2000-2100 | 190 | 10.0 | D | 5148 | 118 | 0.2 | 4 | 2 | 76 | 0.2 | 0.2 | 0.5 |
| 12-22 | 1500-1600 | 290 | 5.5 | D | 6438 | 145 | 0.5 | 4 | 2 | 427 | 1.4 | 3.0 | 1.9 |
| | | | | | | | | | | MEAN | 3.3 | 3.9 | 2.1 |
| | | | | | | | | | | STANDARD DEVIATION | 2.3 | 3.3 | 1.0 |
| | | | | | | | | | | CORRELATION WITH $X_{OBS}$ | 0.30 | 0.14 | |

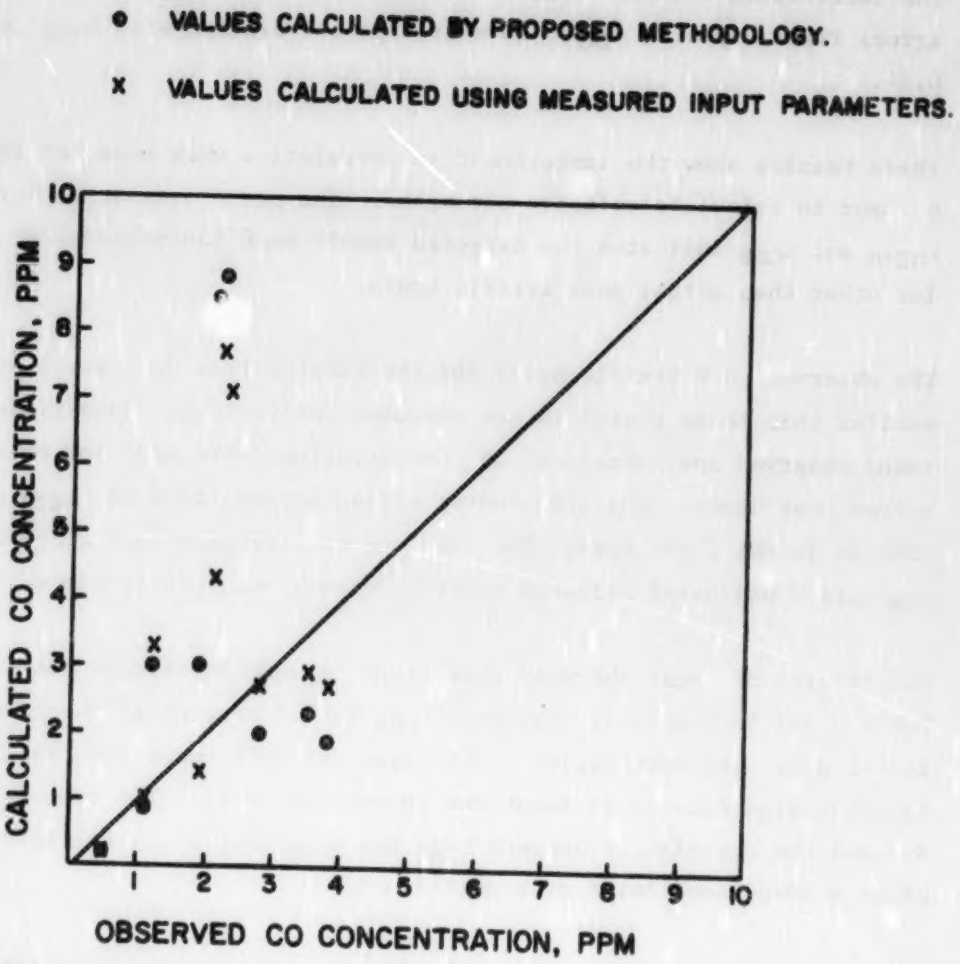


Figure 8. Observed vs. calculated CO concentrations for peak traffic hour stated in the proposed methodology

traffic volume and running time inputs, $X_{METH}$ concentrations were calculated using the methodology entirely, and $X_{OBS}$ are observed concentrations. The mean of $X_{INP}$ is 3.3 ppm, compared to a mean $X_{OBS}$ of 2.1 ppm. The correlation between these is 0.30. The mean of $X_{METH}$ is 3.9 ppm, which agrees favorably with $X_{INP}$. However, the correlation with $X_{OBS}$ is only 0.14.

These results show the improvement in correlation when measured inputs can be used to calculate emission strengths. The poor correlation between $X_{METH}$ and $X_{OBS}$ indicates the expected result when the methodology is used for other than actual peak traffic hours.

The observed peak traffic hours for the Liberty Tree Mall are 1 hour earlier than those stated in the proposed methodology. Comparisons between observed and calculated CO concentrations were made for these observed peak hours. The area source strengths used to find $X_{METH}$ are the same as in the first case. The area source strengths used to calculate $X_{INP}$ are found using measured traffic volumes and running times.

The results of these observed peak traffic hour comparisons are shown in Table 9 and in Figure 9, The mean $X_{OBS}$ is 1.9 ppm, while the mean $X_{METH}$ is 4.1 ppm. The correlation coefficient for this comparison is 0.53, indicating significance at about the 10-percent level. The mean $X_{INP}$ is 3.7 and the correlation between $X_{INP}$ and $X_{OBS}$ is 0.56, also representing about a 10-percent level of significance.

The correlation coefficient for the 20 pairs of $X_{INP}$ and $X_{OBS}$ for 1-hour periods is 0.40. The mean $X_{INP}$ is 3.5 compared to 2.0 mean $X_{OBS}$. The linear relationship is significant between the 10- and 5-percent levels, and the regression line is given by

$$X_{OBS} = 0.83\, X_{INP} - 0.93.$$

Table 9. PEAK 1-HOUR OBSERVED AND CALCULATED CO CONCENTRATIONS AT LIBERTY TREE MALL FOR OBSERVED PEAK TRAFFIC HOUR. $\chi_{INP}$ VALUES ARE CALCULATED USING MEASURED INPUT PARAMETERS AND ONE STABILITY CLASS LESS STABLE THAN THAT OBSERVED. $\chi_{METH}$ VALUES ARE CALCULATED USING THE PROPOSED METHODOLOGY AND D STABILITY.

| Day | Hour (EST) | Wind Direction (deg) | Wind Speed (m/sec) | Observed stability (class) | Volume (veh/hr) | RT (sec) | Q/U (x $10^4$) | Measurement station (no.) | Background station (no.) | Distance (m) | $\chi_{INP}$ (ppm) | $\chi_{METH}$ (ppm) | $\chi_{OBS}$ (ppm) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 12-11 | 1900-2000 | 320 | 3 | E | 4434 | 134 | 0.6 | 4 | 2 | 427 | 2.3 | 2.9 | 2.0 |
| 12-12 | 1900-2000 | 290 | 1.0 | F | 4356 | 155 | 2.1 | 4 | 2 | 427 | 9.6 | 8.8 | 2.6 |
| 12-13 | 1900-2000 | 160 | 3.0 | E | 4696 | 149 | 0.7 | 3 | 4 | 92 | 1.0 | 0.9 | 0.1 |
| 12-14 | 1900-2000 | 280 | 5.5 | D | 4714 | 131 | 0.4 | 4 | 2 | 580 | 1.3 | 1.9 | 1.7 |
| 12-15 | 1400-1500 | 290 | 2.5 | D | 5713 | 221 | 1.6 | 4 | 2 | 427 | 4.4 | 6.7 | 1.6 |
| 12-18 | 1900-2000 | 280 | 4.5 | E | 5005 | 156 | 0.5 | 4 | 2 | 580 | 2.3 | 2.3 | 2.5 |
| 12-19 | 1900-2000 | 240 | 1.0 | D | 5207 | 176 | 2.9 | 4 | 2 | 3666 | 7.6 | 8.2 | 1.9 |
| 12-20 | 1900-2000 | 360 | 1.0 | D | 5119 | 162 | 2.6 | 4 | 2 | 305 | 6.5 | 7.4 | 3.0 |
| 12-21 | 1900-2000 | 170 | 8.0 | D | 5210 | 162 | 0.3 | 3 | 4 | 92 | 0.4 | 2.4 | 1.3 |
| 12-22 | 1400-1500 | 290 | 6.5 | D | 6492 | 218 | 0.7 | 4 | 2 | 427 | 1.9 | 1.4 | 2.2 |
|  |  |  |  |  |  |  |  |  |  | MEAN | 3.7 | 4.1 | 1.9 |
|  |  |  |  |  |  |  |  |  |  | STANDARD DEVIATION | 3.0 | 3.3 | 0.8 |
|  |  |  |  |  |  |  |  |  |  | CORRELATION WITH $\chi_{OBS}$ | 0.56 | 0.53 |  |

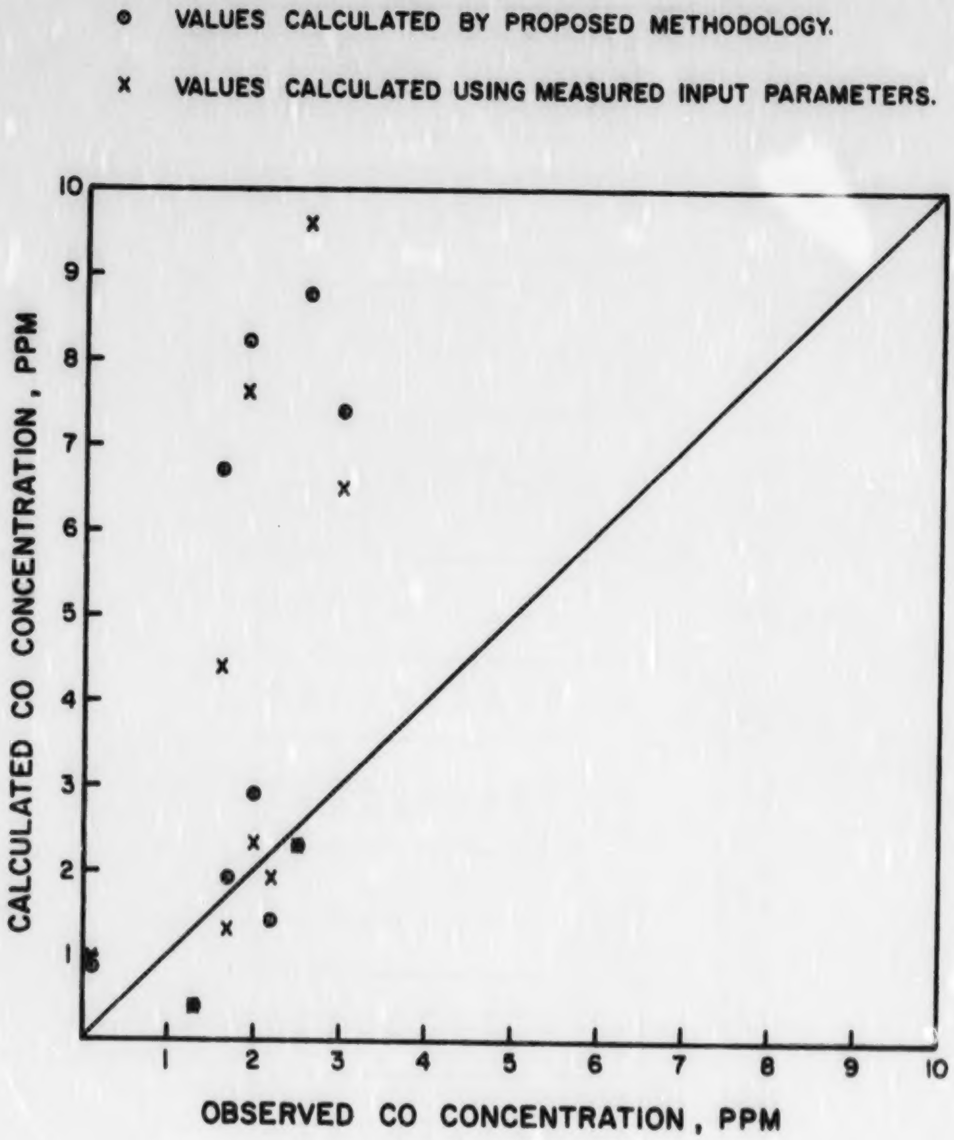


Figure 9. Observed vs. calculated CO concentrations for observed peak traffic hour

This suggests that using the area source curves of the proposed methodology and stabilities one class less stable than those observed is a reasonable technique for calculating average concentrations from area source emission strengths. However, this technique does not adequately explain the variability about an average value.

Comparisons between observed concentrations and those calculated using the proposed methodology were also made for 8-hour peak periods. According to the methodology, the peak 8-hour traffic volume is $3.4 \times 10^{-5}$ ADT (veh/sec) for weekdays and $4.5 \times 10^{-5}$ ADT (veh/sec) for Saturdays. The emission strengths for these cases are $1.8 \times 10^{-4}$ g/m$^2$ - sec for weekdays and $2.4 \times 10^{-4}$ g/m$^2$ - sec for Saturdays. The resulting comparisons are shown in Table 10 and in Figure 10. The mean $\chi_{METH}$ is 2.1 ppm, while $\chi_{OBS}$ has a mean of 1.3 ppm. The $\chi_{METH}$ values include the multiplying factor[1] of 0.8 to denote the variability of meteorological conditions over an 8-hour period. The correlation coefficient for $\chi_{OBS}$ and $\chi_{METH}$ is -0.15. The observed 8-hour to 1-hour concentration ratio was found to be 0.58 (see Table 6). Using this factor gives a mean $\chi_{METH}$ of 1.6 with a correlation coefficient of -0.15.

## COMPARISON OF PEAK TRAFFIC ESTIMATION PARAMETERS

The average round trip generation rate for the Liberty Tree Mall was calculated to be 22, which is near the mean value suggested for use for shopping centers of the same general size.[2] However, the traffic volume counts show that the peak hour volumes are higher than those predicted by the methodology. Table 11 gives the comparative figures for the Geomet Report[2] and the Liberty Tree Mall.

The weekday peak hour traffic is given as 11 percent of the average daily traffic in the Geomet Report, while it was found to be 19 percent at the Liberty Tree Mall. These figures are independent of the average daily traffic correction factor of 1.4 for December. Likewise, the Saturday peak hour was measured to be 18 percent while the Geomet Report (and the

Table 10. PEAK 8-HOUR OBSERVED AND CALCULATED CO CONCENTRATIONS AT THE LIBERTY TREE MALL; $\chi_{METH}$ VALUES ARE CALCULATED USING THE PROPOSED METHODOLOGY

| Day | Hours (EST) | Resultant wind | | Measurement station (no.) | Background station (no.) | Distance (m) | $\chi_{METH}$ (ppm) | $\chi_{OBS}$ (ppm) |
|---|---|---|---|---|---|---|---|---|
| | | Direction (deg) | Speed (m/sec) | | | | | |
| 12-11 | 1300-2100 | 318 | 2.8 | 4 | 2 | 427 | 2.1 | 1.4 |
| 12-12 | 1300-2100 | 307 | 2.2 | 4 | 2 | 427 | 2.6 | 0.9 |
| 12-13 | 1300-2100 | 155 | 2.5 | 3 | 4 | 107 | 0.9 | 0.7 |
| 12-15 | 1000-1800 | 294 | 3.1 | 4 | 2 | 427 | 2.2 | 2.1 |
| 12-18 | 1300-2100 | 289 | 5.0 | 4 | 2 | 427 | 1.1 | 1.8 |
| 12-19 | 1300-2100 | 268 | 1.2 | 4 | 2 | 548 | 6.6 | 0.8 |
| 12-21 | 1300-2100 | 169 | 7.2 | 3 | 4 | 92 | 0.2 | 0.6 |
| 12-22 | 1000-1800 | 291 | 5.6 | 4 | 2 | 488 | 1.4 | 2.0 |
| | | | | | | MEAN | 2.1 | 1.3 |
| | | | | | | STANDARD DEVIATION | 2.0 | 0.6 |
| | | | | | | CORRELATION | -0.15 | |

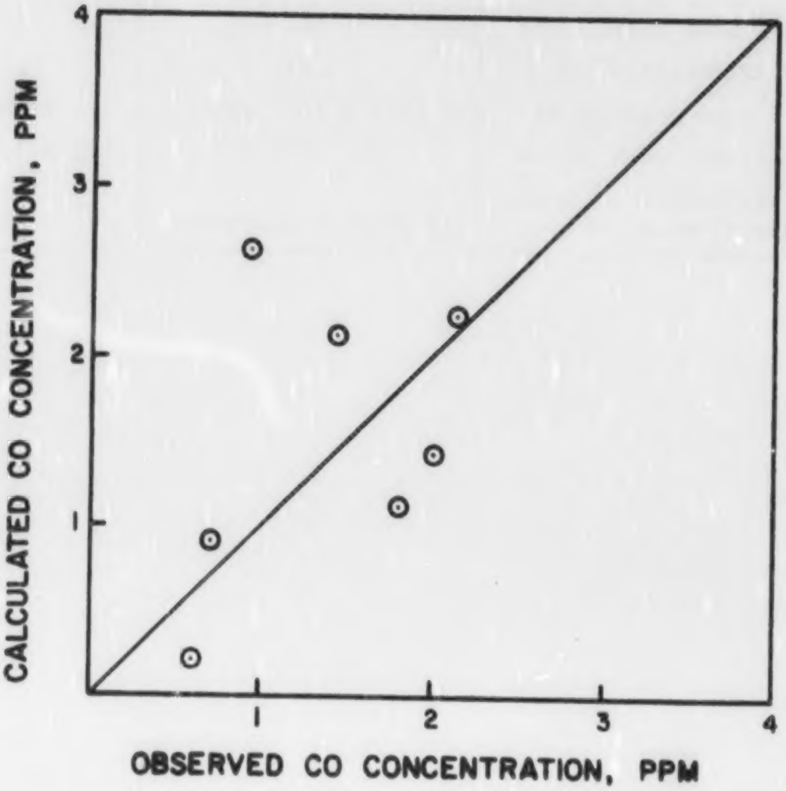


Figure 10. Observed CO concentration vs. concentration calculated by proposed methodology for peak 8 hours

Table 11. COMPARISON OF TRAFFIC VOLUME CALCULATION FACTORS--GEOMET REPORT AND LIBERTY TREE MALL

| | Geomet | Liberty Tree Mall |
|---|---|---|
| Weekday 1 hour % ADT | 11 | 19 |
| Saturday 1 hour % ADT | 15 | 18 |
| Saturday ADT/Weekday ADT | 1.15 | 1.29 |
| Weekday 1 hour peak volume | $4.3 \times 10^{-5}$ ADT | $7.5 \times 10^{-5}$ ADT |
| Saturday 1 hour peak volume | $6.7 \times 10^{-5}$ ADT | $8.5 \times 10^{-5}$ ADT |
| Round trips/1000 $ft.^2$ gross leasible floor space | 18 (median and mean) | 22 |

proposed methodology) lists it as 15 percent. The measured average Saturday traffic was 1.29 times the average weekday traffic, compared to the value of 1.15 given in the methodology.

The peak hour percentages of average daily traffic used in the proposed methodology are based on annual figures and thus perhaps do not reflect a pre-Christmas peak in addition to the December peak. Examination of December daily traffic volumes from other shopping centers should define whether this is a general effect or an isolated occurrence.

## DISCUSSION

The mean emission density calculated from measured input values for the peak hour is 2.3 $g/m^2$ - sec for weekdays and 4.3 $g/m^2$ - sec for Saturdays. These are essentially the same values calculated using the proposed methodology. The observed traffic volumes were higher than those computed by the proposed methodology (Table 11), but the observed running times were lower, leading to equal calculated emission densities. The lower running times could be due to the use of traffic policemen to help direct traffic during the peak December period.

The mean concentrations calculated by both methods are higher than the mean observed value by about a factor of 2. There appears to be a trend to overestimate concentrations at low wind speeds and to underestimate them at moderate wind speeds. This is depicted in Figure 11. A possible explanation for this is that the initial vertical diffusion parameter, $\sigma_{z_0}$, is too low at low wind speeds and too high at higher speeds.

Individual comparisons of the peak 8-hour mean calculated and observed concentrations do not correlate. A probable cause for this is the distance scale involved (of the order of 100 meters) in considering area source emissions and concentrations at shopping centers. Over this distance scale a given percent change in downwind distance will cause a nonlinear, higher percent change in concentration calculated by the area

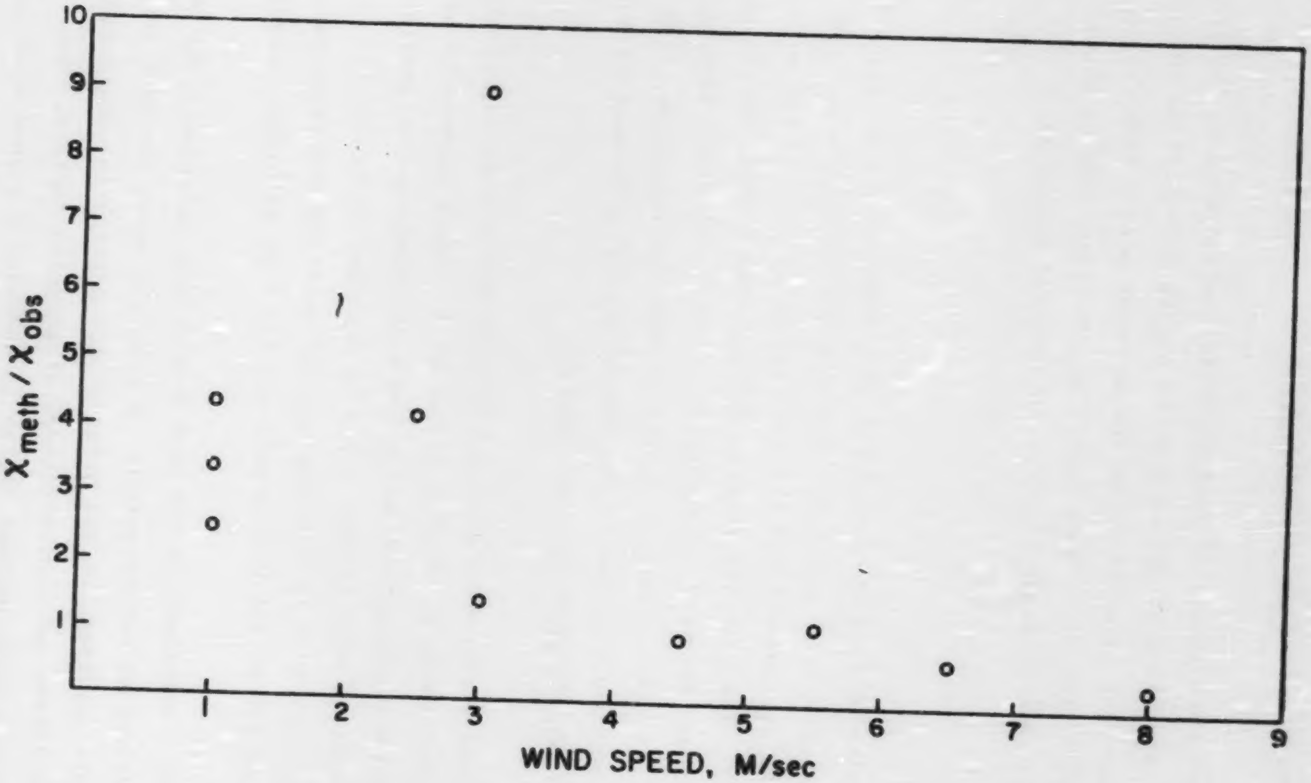


Figure 11. Calculated/observed concentrations ($X_{METH}/X_{OBS}$ from Table 9) versus wind speed

source model. Assuming the background concentration to be isotropic, wind shifts occurring during an 8-hour period will change the downwind distance across the shopping center and hence the concentration at a receptor. Since the effect on concentration is nonlinear, a single resultant wind direction (and downwind distance) will not adequately predict an 8-hour average concentration. Another possible cause for the lack of correlation is the use of the inverse wind speed in the area source model: the inverse of the resultant 8-hour wind speed is not necessarily equal to the 8-hour resultant of the inverse of 1-hour wind speeds.

Table 11 also lists the factors for converting average daily traffic to peak hour flows. The factor calculated for the study period is 1.7 times that of the proposed methodology for weekdays and 1.3 times higher for Saturdays.

The mean 8-hour to 1-hour peak concentration ratio was found to be 0.58 versus the factor of 0.8 due to variable meteorological conditions suggested in the proposed methodology. The methodology assumes that the peak 1-hour traffic volume is 11 percent and the peak 8-hour volume is 70 percent of the average daily traffic for weekdays. If the 1-hour percent is assumed to hold for 8 hours, then it would account for 88 percent of the average daily traffic. This accounts for part of the peak 1-hour to 8-hour ratio:

$$\frac{70}{88} = 0.8.$$

Assuming that this factor holds during the study period and multiplying by the factor or 0.8 for meteorological variations yields 0.64. A similar calculation for Saturday gives 0.53 for an average of 0.62 compared to the observed value of 0.58.

A proposed change in the proposed methodology is a shift in emphasis to consider the concentrations near intersections at the gates to a shopping center as a function of the volume/capacity ratio. During this study, concentrations were measured at the main gate (Gate A) by monitoring station number 1. The exit capacity of this gate is 1150 veh/hr for level of service E. For each day, the peak hour exit volume for Gate A was divided by this capacity to find v/c ratios. After removing the days when the wind direction was from the monitor toward the exit lane, the v/c ratios were divided by the product of the wind speed and the sine of the wind angle to calculate adjusted ratios which were then compared with the measured concentrations for the same hours. The results are displayed in Table 12. The mean adjusted ratio is 0.84 sec/m and the mean concentration is 11.47 ppm. The correlation coefficient is 0.83, which is significant at better than the 1 percent level. A linear fit to the data yields

$$\chi = 7.51 \text{ (adjusted ratio)} + 5.15. \tag{17}$$

However, a correlation of $1/U$ and $\chi$ has a coefficient of 0.86.

Table 12. COMPARISON OF ADJUSTED VOLUME/CAPACITY RATIOS TO CARBON MONOXIDE CONCENTRATIONS MEASURED FOR PEAK TRAFFIC VOLUMES EXITING AT GATE A

| Day | Hour | Volume | V/C | $\theta$ | U | $\frac{V/C}{U \sin \theta}$ | X |
|---|---|---|---|---|---|---|---|
| 12-10 | 2100-2200 | 1000 | 0.87 | 40 | 1.5 | 0.90 | 19.1 |
| 12-11 | 2100-2200 | 940 | 0.82 | 40 | 3.0 | 0.42 | 5.8 |
| 12-12 | 2100-2200 | 900 | 0.78 | 30 | 0.5 | 3.13 | 25.0 |
| 12-14 | 2100-2200 | 920 | 0.80 | 70 | 4.5 | 0.19 | 1.9 |
| 12-15 | 1500-1600 | 890 | 0.77 | 40 | 2.0 | 0.60 | 12.1 |
| 12-18 | 2100-2200 | (1050) | (1) | 40 | 4.5 | 0.35 | 8.0 |
| 12-19 | 2100-2200 | 1000 | 0.87 | 50 | 1.0 | 1.14 | 20.5 |
| 12-22 | 1500-1600 | 1140 | 0.99 | 90 | 2.5 | 0.40 | 4.0 |
| 12-24 | 1100-1200 | 1020 | 0.89 | 30 | 4.0 | 0.44 | 6.8 |

|  |  |  |
|---|---|---|
| MEAN | 0.84 | 11.47 |
| STANDARD DEVIATION | 0.91 | 8.19 |
| CORRELATION | 0.83 |  |

## SECTION VII

## CONCLUSIONS AND RECOMMENDATIONS

### CONCLUSIONS

Based on the results obtained under the conditions of this study the following conclusions are reached:

1. The proposed methodology underestimates the peak-hour traffic volumes and overestimates the running times during the pre-Christmas season. The product of volume and running time, and hence the emission density, is adequately predicted. It is thought that the shorter running times observed at Liberty Tree Mall were caused by the use of traffic policemen during the Christmas rush.

2. The 1-hour mean calculated CO concentration is higher than that observed by about a factor of 2. There is a tendency for the methodology to overestimate at low wind speeds and to underestimate at moderate wind speeds.

3. The proposed methodology is an inadequate estimator of peak 8-hour concentrations. The estimated and observed peak 8-hour concentrations did not correlate. This is thought to result from the highly non-linear concentration versus downwind distance relationship for the distances and emission densities involved. Thus, wind fluctuations over an 8-hour period have a greater impact on concentrations than is reflected in the methodology.

4. The proposed shift of emphasis to considering concentrations based on volume/capacity ratios at gates may be a viable alternative. The volume/capacity ratios for peak exit volumes, after being adjusted for wind speed and angle, had a correlation coefficient of 0.83 when compared with concentrations measured at the same location.

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However, a comparison of concentrations and inverse wind speed yielded a correlation coefficient of 0.86.

## RECOMMENDATIONS

Based on the results obtained under the conditions of this study the following are recommended:

1. Additional monitoring should be done in the vicinity of shopping center gates and intersections to define further the relationships between volume/capacity ratios, traffic signal parameters, and downwind concentrations.
2. The additional monitoring should be complemented by modeling studies to allow extrapolation of the monitoring results.
3. Other existing traffic volume, running time, and average running speed data should be examined for the month of December to determine the factors for calculating peak 1-hour and 8-hour traffic volumes from average daily traffic, and to determine an emission factor more applicable to observed speeds.
4. The effect of meteorological variations on 8-hour concentrations should be examined as a function of the variability in downwind distance to improve the 8-hour concentration estimates.

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# APPENDIX A

## TRAFFIC VOLUMES

Tables A-1 and A-2 show the hourly automatic traffic recorder (ATR) measurements of traffic volumes at the Liberty Tree Mall and on adjacent roadways. Odd-numbered ATR's listed in Table A-1 measure entrance volumes, while exit volumes are measured by the even-numbered ATR's. The volumes listed in Table A-2 are two-way counts. Volumes in parentheses are estimates, based on traffic engineering principles, for periods when machines were inoperative.

Table A-1. TRAFFIC VOLUMES MEASURED AT THE LIBERTY TREE MALL

ATR SUMMARY SHEET
GATE VOLUMES

December 10, 1973

ATR NO.

| | Gate A | | Gate B | | Gate C | | Gate D | | Totals | |
|---|---|---|---|---|---|---|---|---|---|---|
| Time of Day | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | In | Out |
| 0800-0900 | 210 | 50 | 158 | 50 | 57 | (29) | 144 | (46) | 569 | 175 |
| 0900-1000 | 870 | 150 | 364 | 60 | 207 | (57) | 248 | (80) | 1,689 | 347 |
| 1000-1100 | 1,180 | 530 | 436 | 230 | 185 | (172) | 270 | (118) | 2,071 | 1,050 |
| 1100-1200 | 990 | 790 | 413 | 450 | 219 | (285) | 271 | (215) | 1,893 | 1,740 |
| 1200-1300 | 1,050 | 850 | 457 | 540 | 136 | (313) | 228 | (210) | 1,871 | 1,913 |
| 1300-1400 | 990 | 850 | 397 | 510 | 181 | (320) | 268 | (273) | 1,836 | 1,953 |
| 1400-1500 | 880 | 830 | 378 | 450 | 126 | (297) | 237 | (240) | 1,621 | 1,817 |
| 1500-1600 | 940 | 800 | 365 | 410 | 134 | (290) | 253 | (273) | 1,692 | 1,773 |
| 1600-1700 | 820 | 800 | 357 | 450 | 190 | (307) | 258 | 320 | 1,625 | 1,877 |
| 1700-1800 | 1,020 | 700 | 330 | 410 | 164 | (293) | 297 | 386 | 1,811 | 1,789 |
| 1800-1900 | 1,390 | 680 | 388 | 360 | 230 | (259) | 440 | 283 | 2,448 | 1,582 |
| 1900-2000 | 1,680 | 750 | 518 | 470 | 229 | (313) | 552 | 378 | 2,979 | 1,911 |
| 2000-2100 | 1,090 | 970 | 366 | 610 | 106 | (404) | 282 | 483 | 1,844 | 2,467 |
| 2100-2200 | 440 | 1,000 | 203 | 480 | 60 | (377) | 119 | 446 | 822 | 2,303 |
| 2200-2230 | 90 | 460 | 71 | 240 | 23 | (194) | 46 | 290 | 230 | 1,184 |
| 2230-2300 | 50 | 190 | 20 | 90 | 5 | (69) | 7 | 74 | 82 | 423 |
| Total | 13,690 | 10,400 | 5,221 | 5,810 | 2,252 | 3,979 | 3,920 | 4,115 | 25,083 | 24,304 |

**Note: ATRs 1, 3, 5 and 7 are inbound**
**ATRs 2, 4, 6 and 8 are outbound**

Table A-1 (cont). TRAFFIC VOLUMES MEASURED AT THE LIBERTY TREE MALL

ATR SUMMARY SHEET
GATE VOLUMES

December 11, 1973

ATR NO.

| Time of Day | Gate A | | Gate B | | Gate C | | Gate D | | Totals | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | In | Out |
| 0800-0900 | 210 | 40 | 122 | 50 | 68 | (27) | 136 | 46 | 536 | 163 |
| 0900-1000 | 640 | 110 | 284 | 80 | 155 | (53) | 186 | 76 | 1,265 | 319 |
| 1000-1100 | 920 | 430 | 375 | 200 | 188 | (147) | 212 | 114 | 1,695 | 891 |
| 1100-1200 | 830 | 650 | 365 | 320 | 197 | (233) | 175 | 208 | 1,567 | 1,411 |
| 1200-1300 | 890 | 710 | 376 | 410 | 170 | (262) | 221 | 204 | 1,657 | 1,586 |
| 1300-1400 | 860 | 780 | 394 | 430 | 164 | (292) | 216 | 264 | 1,634 | 1,766 |
| 1400-1500 | 810 | 750 | 351 | 370 | 182 | (268) | 191 | 232 | 1,534 | 1,620 |
| 1500-1600 | 790 | 670 | 358 | 370 | 179 | (258) | 232 | 262 | 1,559 | 1,560 |
| 1600-1700 | 710 | 660 | 369 | 390 | 246 | (267) | 248 | 300 | 1,573 | 1,617 |
| 1700-1800 | 820 | 560 | 407 | 360 | 189 | (257) | 239 | 379 | 1,655 | 1,556 |
| 1800-1900 | 1,330 | 560 | 392 | 320 | 224 | (223) | 400 | 245 | 2,346 | 1,348 |
| 1900-2000 | (1,411) | 670 | 558 | 430 | 290 | (274) | 516 | 285 | 2,775 | 1,659 |
| 2000-2100 | (1,086) | 820 | 438 | 600 | 162 | (380) | 302 | 498 | 1,988 | 2,298 |
| 2100-2200 | (462) | 940 | 293 | 550 | 77 | (387) | 135 | 463 | 967 | 2,340 |
| 2200-2230 | (77) | 500 | 70 | 260 | 21 | (195) | 44 | 225 | 212 | 1,180 |
| 2230-2300 | (43) | 170 | 23 | 90 | 7 | (102) | 15 | 255 | 88 | 617 |
| **Total** | 11,889 | 9,020 | 5,175 | 5,230 | 2,519 | 3,625 | 3,468 | 4,056 | 23,051 | 21,931 |

**Note:** ATRs 1, 3, 5 and 7 are inbound
ATRs 2, 4, 6 and 8 are outbound

## Table A-1 (cont). TRAFFIC VOLUMES MEASURED AT THE LIBERTY TREE MALL

ATR SUMMARY SHEET
GATE VOLUMES

December 12, 1973

ATR NO.

| Time of Day | Gate A 1 | Gate A 2 | Gate B 3 | Gate B 4 | Gate C 5 | Gate C 6 | Gate D 7 | Gate D 8 | Totals In | Totals Out |
|---|---|---|---|---|---|---|---|---|---|---|
| 0800-0900 | (280) | 40 | 132 | 40 | 65 | (30) | 137 | 69 | 614 | 179 |
| 0900-1000 | 630 | 120 | 209 | 80 | 162 | (49) | 174 | 48 | 1,175 | 297 |
| 1000-1100 | 960 | 350 | 325 | 230 | 144 | (132) | 230 | 81 | 1,659 | 793 |
| 1100-1200 | 860 | 590 | 391 | 370 | 148 | (228) | 192 | 182 | 1,591 | 1,370 |
| 1200-1300 | 980 | 660 | 415 | 470 | 236 | (270) | 264 | 226 | 1,895 | 1,626 |
| 1300-1400 | 910 | 710 | 376 | 520 | 202 | (295) | 210 | 248 | 1,698 | 1,773 |
| 1400-1500 | 860 | 640 | 374 | 420 | 180 | (257) | 205 | 232 | 1,619 | 1,549 |
| 1500-1600 | 850 | 600 | 354 | 390 | 217 | (249) | 232 | 258 | 1,653 | 1,497 |
| 1600-1700 | 760 | 720 | 332 | 390 | 232 | (284) | 282 | 314 | 1,606 | 1,708 |
| 1700-1800 | 920 | 620 | 378 | 370 | 162 | (271) | 299 | 372 | 1,759 | 1,633 |
| 1800-1900 | 1,250 | 560 | 367 | 360 | 246 | (238) | 358 | 277 | 2,221 | 1,435 |
| 1900-2000 | 1,570 | 660 | 461 | 430 | 289 | (271) | 403 | 272 | 2,723 | 1,633 |
| 2000-2100 | 1,060 | 800 | 372 | 530 | 164 | (349) | 220 | 420 | 1,816 | 2,099 |
| 2100-2200 | 430 | 900 | 270 | 480 | 74 | (347) | 111 | 359 | 885 | 2,086 |
| 2200-2230 | 90 | 600 | 66 | 210 | 27 | (177) | 43 | 79 | 226 | 1,066 |
| 2230-2300 | 50 | 650 | 22 | 160 | 3 | (172) | 15 | 52 | 90 | 1,034 |
| **Total** | 12,460 | 9,220 | 4,844 | 5,450 | 2,551 | 3,619 | 3,375 | 3,489 | 23,230 | 21,778 |

**Note:** ATRs 1, 3, 5 and 7 are inbound
ATRs 2, 4, 6 and 8 are outbound

## Table A-1 (cont). TRAFFIC VOLUMES MEASURED AT THE LIBERTY TREE MALL

### ATR SUMMARY SHEET
### GATE VOLUMES

December 13, 1973

ATR NO.

| Time of Day | Gate A 1 | Gate A 2 | Gate B 3 | Gate B 4 | Gate C 5 | Gate C 6 | Gate D 7 | Gate D 8 | Totals In | Totals Out |
|---|---|---|---|---|---|---|---|---|---|---|
| 0800-0900 | 210 | (49) | 96 | (41) | 64 | (26) | 120 | 43 | 490 | 159 |
| 0900-1000 | 610 | (211) | 192 | (113) | 140 | (81) | 205 | 80 | 1,147 | 485 |
| 1000-1100 | 930 | (389) | 292 | (267) | 213 | (158) | 210 | 135 | 1,645 | 949 |
| 1100-1200 | 820 | (641) | 344 | (413) | 212 | (258) | 207 | 244 | 1,583 | 1,556 |
| 1200-1300 | 910 | 630 | 362 | (470) | 223 | (273) | 287 | 271 | 1,782 | 1,644 |
| 1300-1400 | 880 | 640 | 351 | 360 | 183 | (251) | 216 | 260 | 1,630 | 1,511 |
| 1400-1500 | 820 | 660 | 318 | 370 | 157 | (241) | 242 | 178 | 1,537 | 1,449 |
| 1500-1600 | 840 | 710 | 367 | 390 | 238 | (282) | 255 | 317 | 1,700 | 1,699 |
| 1600-1700 | 830 | 630 | 334 | 390 | 296 | (288) | 297 | 428 | 1,757 | 1,736 |
| 1700-1800 | 1,020 | 610 | 392 | 410 | 270 | (272) | 330 | 346 | 2,012 | 1,638 |
| 1800-1900 | 1,310 | 620 | 387 | 390 | 274 | (259) | 424 | 293 | 2,395 | 1,562 |
| 1900-2000 | 1,600 | 740 | 439 | 470 | 287 | (325) | 411 | 424 | 2,737 | 1,959 |
| 2000-2100 | 1,170 | 830 | 346 | 530 | 137 | (365) | 247 | 472 | 1,900 | 2,197 |
| 2100-2200 | 530 | 910 | 275 | 510 | 72 | (382) | 130 | 498 | 1,007 | 2,300 |
| 2200-2230 | 80 | 400 | 64 | 320 | 9 | (161) | 32 | 86 | 185 | 967 |
| 2230-2300 | 50 | 180 | 22 | 110 | 13 | (68) | 16 | 51 | 101 | 409 |
| Total | 12,610 | 8,850 | 4,581 | 5,554 | 2,788 | 3,690 | 3,629 | 4,126 | 23,608 | 22,220 |

Note: ATRs 1, 3, 5 and 7 are inbound
ATRs 2, 4, 6 and 8 are outbound

Table A-1 (cont). TRAFFIC VOLUMES MEASURED AT THE LIBERTY TREE MALL

ATR SUMMARY SHEET
GATE VOLUMES

December 14, 1973

ATR NO.

| Time of Day | Gate A<br>1 | <br>2 | Gate B<br>3 | <br>4 | Gate C<br>5 | <br>6 | Gate D<br>7 | <br>8 | Totals<br>In | <br>Out |
|---|---|---|---|---|---|---|---|---|---|---|
| 0800-0900 | 230 | 60 | 102 | 60 | 81 | (30) | 154 | 21 | 567 | 171 |
| 0900-1000 | 570 | 120 | 206 | 70 | 163 | (46) | 207 | 27 | 1,146 | 263 |
| 1000-1100 | 870 | 330 | 301 | 200 | 178 | (134) | 222 | (97) | 1,571 | 761 |
| 1100-1200 | 840 | 560 | 303 | 310 | 218 | (217) | 230 | 146 | 1,591 | 1,233 |
| 1200-1300 | 880 | 600 | 323 | 370 | 232 | (241) | 281 | 156 | 1,716 | 1,367 |
| 1300-1400 | 820 | 660 | 320 | 390 | 188 | (263) | 243 | 179 | 1,571 | 1,492 |
| 1400-1500 | 810 | 600 | 293 | 310 | 208 | (232) | 268 | 174 | 1,579 | 1,316 |
| 1500-1600 | 840 | 660 | 331 | 210 | 196 | (228) | 284 | 192 | 1,651 | 1,290 |
| 1600-1700 | 850 | 670 | 307 | 420 | 308 | (295) | 296 | 286 | 1,761 | 1,671 |
| 1700-1800 | 980 | 620 | 369 | 400 | 226 | (265) | 361 | 215 | 1,936 | 1,500 |
| 1800-1900 | 1,370 | 600 | 362 | 350 | 289 | (251) | 441 | 221 | 2,462 | 1,422 |
| 1900-2000 | 1,590 | 670 | 501 | 510 | 333 | (312) | 522 | 276 | 2,946 | 1,768 |
| 2000-2100 | 1,320 | 800 | 417 | 650 | 190 | (389) | 319 | 365 | 2,246 | 2,204 |
| 2100-2200 | 690 | 920 | 321 | 630 | 86 | (409) | 133 | 360 | 1,230 | 2,319 |
| 2200-2230 | 130 | 480 | 86 | 380 | 10 | (224) | 31 | 188 | 257 | 1,272 |
| 2230-2300 | 70 | 220 | 31 | 170 | 9 | (93) | 15 | 46 | 125 | 529 |
| Total | 12,860 | 8,570 | 4,573 | 5,430 | 2,915 | 3,629 | 4,007 | 2,949 | 24,355 | 20,578 |

Note: ATRs 1, 3, 5 and 7 are inbound
ATRs 2, 4, 6 and 8 are outbound

le A-1 (cont). TRAFFIC VOLUMES MEASURED AT THE LIBERTY TREE MALL

ATR SUMMARY SHEET
GATE VOLUMES

December 15, 1973

ATR NO.

| Time of Day | Gate A | | Gate B | | Gate C | | Gate D | | Totals | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | In | Out |
| 0800-0900 | 220 | 60 | 67 | (65) | 104 | (33) | 160 | 29 | 551 | 187 |
| 0900-1000 | 990 | 180 | 283 | (138) | 290 | (84) | 392 | 80 | 1,955 | 482 |
| 1000-1100 | 1,480 | 520 | 430 | (525) | 329 | (267) | 492 | 222 | 2,731 | 1,534 |
| 1100-1200 | 1,380 | 750 | 535 | (663) | 246 | (375) | 434 | 363 | 2,595 | 2,151 |
| 1200-1300 | 1,390 | 790 | 649 | 550 | 363 | (338) | 490 | 262 | 2,892 | 1,940 |
| 1300-1400 | 1,420 | 740 | 769 | 700 | 373 | (398) | 671 | 448 | 3,233 | 2,286 |
| 1400-1500 | 1,330 | 840 | 817 | 710 | 310 | (448) | 685 | 573 | 3,142 | 2,571 |
| 1500-1600 | 1,270 | 890 | 631 | 740 | 324 | (482) | 506 | 658 | 2,731 | 2,770 |
| 1600-1700 | 1,070 | 880 | 540 | 790 | 258 | (479) | 395 | 600 | 2,263 | 2,749 |
| 1700-1800 | 1,020 | 870 | 469 | 670 | 243 | (397) | 357 | 341 | 2,089 | 2,278 |
| 1800-1900 | 1,220 | 740 | 341 | 520 | 225 | (322) | 323 | 266 | 2,109 | 1,848 |
| 1900-2000 | 1,510 | 690 | 424 | 540 | 222 | (303) | 419 | 207 | 2,575 | 1,740 |
| 2000-2100 | 1,210 | 760 | 366 | 590 | 195 | (332) | 225 | 224 | 1,996 | 1,906 |
| 2100-2200 | 670 | 850 | 213 | 600 | 111 | (356) | 152 | 237 | 1,146 | 2,043 |
| 2200-2230 | 120 | 450 | 100 | 360 | (89) | (192) | (38) | (104) | 347 | 1,106 |
| 2230-2300 | (80) | 250 | 43 | (279) | (21) | (122) | (21) | (48) | 165 | 699 |
| Total | 16,380 | 10,260 | 6,677 | 8,440 | 3,703 | 4,928 | 5,760 | 4,662 | 32,520 | 28,290 |

Note: ATRs 1, 3, 5 and 7 are inbound
ATRs 2, 4, 6 and 8 are outbound

Table A-1 (cont). TRAFFIC VOLUMES MEASURED AT THE LIBERTY TREE MALL

ATR SUMMARY SHEET
GATE VOLUMES

December 18, 1973

ATR NO.

| Time of Day | Gate A | | Gate B | | Gate C | | Gate D | | Totals | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | In | Out |
| 0800-0900 | (245) | (49) | (146) | (63) | (77) | (119) | (148) | (46) | 616 | 277 |
| 0900-1000 | (749) | 180 | 279 | (101) | (175) | (79) | (203) | (86) | 1,406 | 446 |
| 1000-1100 | 1,140 | 520 | 418 | (252) | (212) | 108 | (231) | (146) | 2,001 | 1,026 |
| 1100-1200 | 1,040 | 800 | 453 | 480 | 360 | 158 | (191) | (264) | 2,044 | 1,702 |
| 1200-1300 | 1,110 | (876) | 483 | 520 | (192) | 408 | 262 | 272 | 2,047 | 2,076 |
| 1300-1400 | 1,090 | (956) | 541 | 540 | 170 | 404 | 250 | 360 | 2,051 | 2,260 |
| 1400-1500 | 830 | (916) | 452 | 480 | 232 | 382 | 209 | 265 | 1,723 | 2,043 |
| 1500-1600 | 930 | (825) | 430 | 460 | (202) | 327 | 236 | 362 | 1,798 | 1,974 |
| 1600-1700 | 820 | (815) | 434 | 500 | 231 | 307 | 279 | 308 | 1,764 | 1,950 |
| 1700-1800 | 1,010 | (684) | 391 | 460 | (214) | 242 | 306 | 292 | 1,921 | 1,678 |
| 1800-1900 | 1,330 | (684) | 430 | 390 | (253) | 260 | 463 | 250 | 2,476 | 1,584 |
| 1900-2000 | 1,650 | (825) | 687 | 530 | 170 | 322 | 587 | 234 | 3,094 | 1,911 |
| 2000-2100 | 1,270 | (1,007) | 547 | 660 | (183) | 375 | 337 | 434 | 2,337 | 2,476 |
| 2100-2200 | 540 | (1,157) | 322 | 660 | (87) | 275 | 129 | 401 | 1,078 | 2,493 |
| 2200-2230 | 90 | (610) | 65 | 360 | (24) | 147 | 29 | 203 | 208 | 1,320 |
| 2230-2300 | 50 | (207) | 23 | 130 | (8) | 77 | 14 | 82 | 95 | 496 |
| Total | 13,894 | 11,111 | 6,101 | 6,586 | 2,790 | 3,990 | 3,874 | 4,025 | 26,659 | 25,712 |

Note: ATRs 1, 3, 5 and 7 are inbound
ATRs 2, 4, 6 and 8 are outbound

## e A-1 (cont). TRAFFIC VOLUMES MEASURED AT THE LIBERTY TREE MALL

### ATR SUMMARY SHEET
### GATE VOLUMES

December 19, 1973

ATR NO.

| Time of Day | Gate A<br>1 | 2 | Gate B<br>3 | 4 | Gate C<br>5 | 6 | Gate D<br>7 | 8 | Totals<br>In | Out |
|---|---|---|---|---|---|---|---|---|---|---|
| 0800-0900 | 200 | (45) | 95 | (53) | (75) | (26) | 114 | (26) | 484 | 150 |
| 0900-1000 | 700 | 120 | 233 | (106) | (188) | (59) | 235 | (59) | 1,356 | 344 |
| 1000-1100 | 1,140 | 490 | 406 | (306) | (167) | (208) | 277 | (207) | 1,990 | 1,211 |
| 1100-1200 | 1,010 | 730 | 494 | (492) | 156 | (319) | 237 | (319) | 1,897 | 1,860 |
| 1200-1300 | 1,090 | 830 | 516 | (625) | 207 | (381) | 291 | (381) | 2,104 | 2,217 |
| 1300-1400 | 1,090 | 860 | 520 | (692) | 262 | (405) | 289 | (405) | 2,161 | 2,362 |
| 1400-1500 | 950 | 880 | 460 | 540 | 182 | (371) | 260 | (370) | 1,852 | 2,161 |
| 1500-1600 | 990 | 860 | 446 | 480 | 252 | (350) | 275 | (349) | 1,963 | 2,039 |
| 1600-1700 | 910 | 830 | 497 | 500 | 269 | (348) | 266 | (347) | 1,942 | 2,025 |
| 1700-1800 | 1,050 | 830 | 427 | 540 | 193 | (358) | 351 | (357) | 2,021 | 2,085 |
| 1800-1900 | 1,450 | 670 | 468 | 420 | 313 | (285) | 492 | (284) | 2,723 | 1,659 |
| 1900-2000 | 1,580 | 710 | 678 | 620 | 300 | (348) | 624 | (347) | 3,182 | 2,025 |
| 2000-2100 | 1,360 | 880 | 560 | 740 | 206 | (423) | 361 | (423) | 2,487 | 2,466 |
| 2100-2200 | 690 | 1,000 | 341 | 670 | 128 | (436) | 148 | (435) | 1,307 | 2,541 |
| 2200-2230 | 110 | 550 | 80 | 330 | 20 | (230) | 39 | (230) | 249 | 1,340 |
| 2230-2300 | 60 | 250 | 25 | 140 | 67 | (102) | 17 | (101) | 169 | 593 |
| **Total** | 14,380 | 10,535 | 6,246 | 7,254 | 2,985 | 4,649 | 4,276 | 4,640 | 27,887 | 27,078 |

**Note:** ATRs 1, 3, 5 and 7 are inbound
ATRs 2, 4, 6 and 8 are outbound

Table A-1 (cont). TRAFFIC VOLUMES MEASURED AT THE LIBERTY TREE MALL

ATR SUMMARY SHEET
GATE VOLUMES

December 20, 1973

ATR NO.

| Time of Day | Gate A 1 | Gate A 2 | Gate B 3 | Gate B 4 | Gate C 5 | Gate C 6 | Gate D 7 | Gate D 8 | Totals In | Totals Out |
|---|---|---|---|---|---|---|---|---|---|---|
| 0800-0900 | 230 | 60 | 87 | 50 | 105 | 105 | 136 | 65 | 558 | 280 |
| 0900-1000 | 720 | 260 | 273 | 140 | 156 | 98 | 250 | 49 | 1,399 | 547 |
| 1000-1100 | 1,020 | 480 | 411 | 330 | 198 | 229 | 307 | 143 | 1,936 | 1,182 |
| 1100-1200 | 1,050 | 790 | 465 | 510 | 234 | 303 | 312 | 255 | 2,061 | 1,858 |
| 1200-1300 | 1,070 | 870 | 523 | 580 | 237 | 328 | 341 | 283 | 2,171 | 2,061 |
| 1300-1400 | 960 | 830 | 485 | 490 | 184 | 341 | 281 | 291 | 1,910 | 1,952 |
| 1400-1500 | 910 | 840 | 418 | 470 | 221 | 381 | 280 | 244 | 1,829 | 1,935 |
| 1500-1600 | 1,000 | 820 | 461 | 430 | 233 | 450 | 313 | 298 | 2,007 | 1,998 |
| 1600-1700 | 900 | 860 | 408 | 450 | 348 | 312 | 320 | 366 | 1,976 | 1,988 |
| 1700-1800 | 1,090 | 800 | 438 | 480 | 212 | 323 | 426 | 345 | 2,166 | 1,948 |
| 1800-1900 | 1,360 | 820 | 440 | 460 | 241 | 334 | 485 | 295 | 2,526 | 1,909 |
| 1900-2000 | 1,510 | 750 | 601 | 570 | 342 | 287 | 636 | 423 | 3,089 | 2,030 |
| 2000-2100 | 1,360 | 920 | 526 | 680 | 274 | 340 | 339 | (496) | 2,499 | 2,436 |
| 2100-2200 | 710 | 1,110 | 398 | 720 | 123 | 280 | 194 | (523) | 1,425 | 2,633 |
| 2200-2230 | 150 | 570 | 122 | 330 | 79 | 155 | 39 | (90) | 390 | 1,145 |
| 2230-2300 | 50 | 390 | 25 | 200 | 23 | 137 | 23 | (54) | 121 | 781 |
| Total | 14,090 | 11,170 | 6,081 | 6,890 | 3,210 | 4,403 | 4,682 | 4,220 | 28,063 | 26,683 |

Note: ATRs 1, 3, 5 and 7 are inbound
ATRs 2, 4, 6 and 8 are outbound

e A-1 (cont). TRAFFIC VOLUMES EASURED AT THE LIBERTY TREE MALL

ATR SUMMARY SHEET
GATE VOLUMES

December 21, 1973

ATR NO.

| Time of Day | Gate A<br>1 | 2 | Gate B<br>3 | 4 | Gate C<br>5 | 6 | Gate D<br>7 | 8 | Totals<br>In | Out |
|---|---|---|---|---|---|---|---|---|---|---|
| 0800-0900 | 250 | 80 | 122 | 50 | 65 | (33) | 125 | (36) | 562 | 199 |
| 0900-1000 | 660 | 160 | 298 | 130 | 153 | (67) | 287 | (46) | 1,398 | 403 |
| 1000-1100 | 960 | 470 | 421 | 330 | 218 | (193) | 306 | (167) | 1,905 | 1,160 |
| 1100-1200 | 1,010 | 780 | 450 | 450 | 299 | (315) | 297 | 350 | 2,056 | 1,895 |
| 1200-1300 | 1,050 | 760 | 508 | 480 | 319 | (313) | 338 | 333 | 2,215 | 1,886 |
| 1300-1400 | 1,050 | 780 | 505 | 460 | 286 | (313) | 291 | 328 | 2,132 | 1,881 |
| 1400-1500 | 1,010 | 840 | 439 | 440 | 310 | (314) | 323 | 298 | 2,082 | 1,892 |
| 1500-1600 | 1,020 | 910 | 524 | 490 | 371 | (350) | 353 | 358 | 2,268 | 2,108 |
| 1600-1700 | 1,080 | 930 | 510 | 490 | 403 | (369) | 402 | 433 | 2,395 | 2,222 |
| 1700-1800 | 1,060 | 870 | 512 | 660 | 249 | (402) | 385 | 487 | 2,206 | 2,419 |
| 1800-1900 | 1,200 | 740 | 436 | 470 | 327 | (313) | 452 | 363 | 2,415 | 1,886 |
| 1900-2000 | 1,550 | 720 | 609 | 550 | 502 | (330) | 563 | 386 | 3,224 | 1,986 |
| 2000-2100 | 1,430 | 860 | 550 | 700 | 312 | (414) | 362 | 520 | 2,654 | 2,494 |
| 2100-2200 | 910 | (1,196) | 448 | 630 | 204 | (469) | 205 | 527 | 1,767 | 2,822 |
| 2200-2230 | 150 | (624) | 112 | 450 | 80 | (265) | 37 | 258 | 379 | 1,597 |
| 2230-2300 | 80 | (286) | 44 | 220 | 46 | (127) | 30 | 133 | 200 | 766 |
| Total | 14,470 | 11,006 | 6,488 | 7,000 | 4,144 | 4,587 | 4,756 | 5,023 | 29,858 | 27,616 |

**Note:** ATRs 1, 3, 5 and 7 are inbound
ATRs 2, 4, 6 and 8 are outbound

Table A-1 (cont). TRAFFIC VOLUMES MEASURED AT THE LIBERTY TREE MALL

ATR SUMMARY SHEET
GATE VOLUMES

December 22, 1973

ATR NO.

| Time of Day | Gate A 1 | Gate A 2 | Gate B 3 | Gate B 4 | Gate C 5 | Gate C 6 | Gate D 7 | Gate D 8 | Totals In | Totals Out |
|---|---|---|---|---|---|---|---|---|---|---|
| 0800-0900 | 220 | (68) | 82 | 70 | 95 | (41) | 130 | 41 | 527 | 220 |
| 0900-1000 | 1,020 | (205) | 336 | 150 | 206 | 144 | 320 | 97 | 1,882 | 596 |
| 1000-1100 | 1,530 | (593) | 631 | 570 | 329 | 385 | 519 | 340 | 3,009 | 1,888 |
| 1100-1200 | 1,480 | (833) | 754 | 720 | 370 | 508 | 636 | 577 | 3,240 | 2,638 |
| 1200-1300 | 1,500 | 950 | 828 | 810 | 440 | 549 | 689 | 660 | 3,457 | 2,969 |
| 1300-1400 | 1,390 | 880 | 971 | (749) | 369 | 485 | 792 | 823 | 3,522 | 2,937 |
| 1400-1500 | 1,370 | 930 | 971 | (760) | 350 | 555 | 719 | 837 | 3,410 | 3,082 |
| 1500-1600 | 1,280 | 1,140 | 839 | (792) | 352 | 656 | 581 | 798 | 3,052 | 3,386 |
| 1600-1700 | 1,120 | 1,000 | 651 | 810 | 293 | 440 | 509 | 648 | 2,573 | 2,898 |
| 1700-1800 | 1,010 | 870 | 519 | 710 | 292 | 316 | 369 | 378 | 2,190 | 2,274 |
| 1800-1900 | 1,100 | 790 | 397 | 560 | 231 | 265 | 374 | 264 | 2,102 | 1,879 |
| 1900-2000 | 1,390 | 770 | 459 | 520 | 211 | 194 | 417 | 230 | 2,477 | 1,714 |
| 2000-2100 | 1,210 | 820 | 445 | 570 | 282 | 297 | 324 | 230 | 2,261 | 1,917 |
| 2100-2200 | 730 | 1,000 | 494 | 710 | 159 | 345 | 176 | 236 | 1,559 | 2,291 |
| 2200-2230 | 140 | 390 | 102 | 270 | 102 | 157 | 42 | 132 | 386 | 949 |
| 2230-2300 | 80 | 320 | 39 | 210 | 24 | 88 | 24 | 62 | 167 | 680 |
| Total | 16,570 | 11,559 | 8,518 | 8,981 | 4,105 | 5,425 | 6,621 | 6,353 | 35,814 | 32,318 |

Note: ATRs 1, 3, 5 and 7 are inbound
ATRs 2, 4, 6 and 8 are outbound

## Table A-1 (cont). TRAFFIC VOLUMES MEASURED AT THE LIBERTY TREE MALL

ATR SUMMARY SHEET
GATE VOLUMES

December 24, 1973

ATR NO.

| Time of Day | Gate A 1 | Gate A 2 | Gate B 3 | Gate B 4 | Gate C 5 | Gate C 6 | Gate D 7 | Gate D 8 | Totals In | Totals Out |
|---|---|---|---|---|---|---|---|---|---|---|
| 0800-0900 | 310 | (59) | 124 | 70 | 122 | 85 | 164 | 65 | 720 | 279 |
| 0900-1000 | 300 | (177) | 463 | (84) | 325 | 236 | 563 | 157 | 1,651 | 654 |
| 1000-1100 | 1,600 | 690 | 730 | (322) | 565 | 506 | 806 | 476 | 3,701 | 1,994 |
| 1100-1200 | 1,480 | 1,020 | 874 | (630) | 626 | 666 | 813 | 756 | 3,793 | 3,072 |
| 1200-1300 | 1,330 | 930 | 939 | (756) | 494 | 505 | 665 | 802 | 3,428 | 2,993 |
| 1300-1400 | 1,400 | 880 | 751 | 820 | 498 | 557 | 679 | 701 | 3,328 | 2,958 |
| 1400-1500 | 1,280 | 980 | 725 | 1,100 | 427 | 577 | 601 | 759 | 3,033 | 3,416 |
| 1500-1600 | 1,140 | 950 | 575 | 580 | 282 | 491 | 461 | 567 | 2,458 | 2,588 |
| 1600-1700 | 860 | 950 | 477 | 390 | 244 | 364 | 315 | 290 | 1,896 | 1,994 |
| 1700-1800 | 530 | 860 | 269 | 279 | 227 | 244 | 206 | 208 | 1,232 | 1,582 |
| 1800-1900 | | | | | | | | | | |
| 1900-2000 | | | | | | | | | | |
| 2000-2100 | | | | | | | | | | |
| 2100-2200 | | | | | | | | | | |
| 2200-2230 | | | | | | | | | | |
| 2230-2300 | | | | | | | | | | |
| Total | 10,230 | 7,496 | 5,927 | 5,022 | 3,810 | 4,231 | 5,273 | 4,781 | 25,240 | 21,530 |

Note: ATRs 1, 3, 5 and 7 are inbound
ATRs 2, 4, 6 and 8 are outbound

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## Table A-2. TRAFFIC VOLUMES MEASURED ON ROADWAYS ADJACENT TO THE LIBERTY TREE MALL

ATR SUMMARY SHEET
ADJACENT ROADWAY VOLUMES
December 10, 1973

ATR NO.

| Time of Day | 9<br>Endicott St. | 10<br>Sylvan St. | 11<br>Ash St. |
|---|---|---|---|
| 0800-0900 | 628 | (591) | 74 |
| 0900-1000 | 1,501 | (610) | 166 |
| 1000-1100 | 1,848 | (621) | 128 |
| 1100-1200 | 1,785 | (670) | 190 |
| 1200-1300 | 649 | (798) | 164 |
| 1300-1400 | 1,397 | 830 | 227 |
| 1400-1500 | 1,586 | 810 | 206 |
| 1500-1600 | 1,670 | 920 | 260 |
| 1600-1700 | 1,743 | 860 | 215 |
| 1700-1800 | 1,901 | 820 | 233 |
| 1800-1900 | 1,922 | 800 | 236 |
| 1900-2000 | 2,111 | 730 | 220 |
| 2000-2100 | (1,908) | 640 | 165 |
| 2100-2200 | (1,468) | 500 | 93 |
| 2200-2230 | (883) | 270 | 49 |
| 2230-2300 | (291) | 50 | 20 |
| Total | (23,291) | 10,520 | 2,646 |

Note: Volumes represent two-way counts

Table A-2 (cont). TRAFFIC VOLUMES MEASURED ON ROADWAYS ADJACENT TO THE LIBERTY TREE MALL

ATR SUMMARY SHEET
ADJACENT ROADWAY VOLUMES

December 11, 1973

ATR NO.

| Time of Day | 9<br>Endicott St. | 10<br>Sylvan St. | 11<br>Ash St. |
|---|---|---|---|
| 0800-0900 | 556 | 600 | 162 |
| 0900-1000 | 937 | 620 | 174 |
| 1000-1100 | 1,365 | 630 | 85 |
| 1100-1200 | 1,418 | 680 | 113 |
| 1200-1300 | 1,575 | 810 | 174 |
| 1300-1400 | 464 | 730 | 119 |
| 1400-1500 | 1,680 | 750 | 161 |
| 1500-1600 | 1,680 | 920 | 209 |
| 1600-1700 | 1,554 | 920 | 210 |
| 1700-1800 | 1,565 | 850 | 201 |
| 1800-1900 | 1,754 | 750 | 191 |
| 1900-2000 | 2,006 | 810 | 144 |
| 2000-2100 | 1,691 | 710 | 192 |
| 2100-2200 | 1,302 | 570 | 112 |
| 2200-2230 | 525 | 320 | 80 |
| 2230-2300 | 258 | 200 | 36 |
| Total | 20,330 | 10,870 | 2,363 |

Note: Volumes represent two-way counts

## Table A-2 (cont). TRAFFIC VOLUMES MEASURED ON ROADWAYS ADJACENT TO THE LIBERTY TREE MALL

ATR SUMMARY SHEET
ADJACENT ROADWAY VOLUMES

December 12, 1973

ATR NO.

| Time of Day | 9<br>Endicott St. | 10<br>Sylvan St. | 11<br>Ash St. |
|---|---|---|---|
| 0800-0900 | 525 | 650 | 128 |
| 0900-1000 | 958 | 670 | 123 |
| 1000-1100 | 1,428 | 580 | 170 |
| 1100-1200 | 1,565 | 750 | 139 |
| 1200-1300 | 1,775 | 780 | 239 |
| 1300-1400 | 1,638 | 780 | 202 |
| 1400-1500 | 1,659 | 810 | 195 |
| 1500-1600 | 1,796 | 1,010 | 233 |
| 1600-1700 | 1,701 | 1,010 | 264 |
| 1700-1800 | 1,785 | 820 | 157 |
| 1800-1900 | 1,806 | 810 | 118 |
| 1900-2000 | 2,289 | 750 | 175 |
| 2000-2100 | 1,649 | 670 | 106 |
| 2100-2200 | 1,155 | 500 | 105 |
| 2200-2230 | 433 | 300 | 57 |
| 2230-2300 | 82 | 150 | 37 |
| Total | 22,244 | 11,040 | 2,448 |

Note: Volumes represent two-way counts

Table A-2 (cont). TRAFFIC VOLUMES MEASURED ON ROADWAYS ADJACENT TO THE LIBERTY TREE MALL

### ATR SUMMARY SHEET
### ADJACENT ROADWAY VOLUMES

December 13, 1973

ATR NO.

| Time of Day | 9<br>Endicott St. | 10<br>Sylvan St. | 11<br>Ash St. |
|---|---|---|---|
| 0800-0900 | (473) | 680 | 94 |
| 0900-1000 | (871) | 710 | 95 |
| 1000-1100 | (1,217) | 670 | 115 |
| 1100-1200 | (1,420) | 690 | 143 |
| 1200-1300 | (1,574) | 880 | 252 |
| 1300-1400 | (1,507) | (888) | 210 |
| 1400-1500 | (1,402) | (947) | 175 |
| 1500-1600 | (1,469) | (1,089) | 216 |
| 1600-1700 | (1,479) | (1,097) | 260 |
| 1700-1800 | (1,641) | (1,106) | 174 |
| 1800-1900 | (1,651) | (1,005) | 170 |
| 1900-2000 | (1,731) | (921) | 171 |
| 2000-2100 | (1,682) | (921) | 125 |
| 2100-2200 | (1,324) | (653) | 150 |
| 2200-2230 | (520) | (310) | 116 |
| 2230-2300 | ([illegible]69) | (200) | 32 |
| Total | 20,312 | 12,767 | 2,498 |

Note: Volumes represent two-way counts

Table A-2 (cont). TRAFFIC VOLUMES MEASURED ON ROADWAYS ADJACENT TO THE LIBERTY TREE MALL

ATR SUMMARY SHEET
ADJACENT ROADWAY VOLUMES

December 14, 1973

ATR NO.

| Time of Day | 9 Endicott St. | 10 Sylvan St. | 11 Ash St. |
|---|---|---|---|
| 0800-0900 | 422 | (506) | 166 |
| 0900-1000 | 833 | (542) | 80 |
| 1000-1100 | 1,246 | 560 | 109 |
| 1100-1200 | 1,487 | 660 | 140 |
| 1200-1300 | 1,525 | 760 | 221 |
| 1300-1400 | 1,124 | 750 | 195 |
| 1400-1500 | 1,502 | 780 | 147 |
| 1500-1600 | 1,449 | 860 | 285 |
| 1600-1700 | 1,649 | 970 | 235 |
| 1700-1800 | 1,838 | 970 | 293 |
| 1800-1900 | 1,964 | 840 | 227 |
| 1900-2000 | 1,880 | (785) | 225 |
| 2000-2100 | 1,932 | (785) | 217 |
| 2100-2200 | 1,101 | 600 | 139 |
| 2200-2230 | 293 | 320 | 88 |
| 2230-2300 | 86 | 180 | 54 |
| Total | 20,331 | 10,868 | 2,821 |

Note: Volumes represent two-way counts

Table A-2 (cont). TRAFFIC VOLUMES MEASURED ON ROADWAYS ADJACENT TO THE LIBERTY TREE MALL

## ATR SUMMARY SHEET
## ADJACENT ROADWAY VOLUMES

December 15, 1973

ATR NO.

| Time of Day | 9<br>Endicott St. | 10<br>Sylvan St. | 11<br>Ash St. |
|---|---|---|---|
| 0800-0900 | (340) | 440 | 62 |
| 0900-1000 | 1,460 | 720 | 198 |
| 1000-1100 | 2,184 | 850 | 199 |
| 1100-1200 | 2,258 | 950 | 219 |
| 1200-1300 | 2,510 | 1,000 | 312 |
| 1300-1400 | 2,048 | (1,096) | 362 |
| 1400-1500 | (2,350) | (1,042) | 315 |
| 1500-1600 | (2,160) | 1,060 | 224 |
| 1600-1700 | (1,944) | 1,040 | 220 |
| 1700-1800 | (1,810) | 880 | 252 |
| 1800-1900 | (1,702) | 730 | 123 |
| 1900-2000 | (1,923) | 750 | 180 |
| 2000-2100 | (1,690) | 670 | 118 |
| 2100-2200 | (1,439) | 490 | 111 |
| 2200-2230 | (481) | 300 | 84 |
| 2230-2300 | (376) | (145) | |
| Total | 26,675 | 12,163 | 2,979 |

Note: Volumes represent two-way counts

Table A-2 (cont). TRAFFIC VOLUMES MEASURED ON ROADWAYS ADJACENT TO THE LIBERTY TREE MALL

### ATR SUMMARY SHEET
### ADJACENT ROADWAY VOLUMES

December 18, 1973

ATR NO.

| Time of Day | 9 Endicott St. | 10 Sylvan St. | 11 Ash St. |
|---|---|---|---|
| 0800-0900 | (710) | (691) | (79) |
| 0900-1000 | 1,196 | (714) | (177) |
| 1000-1100 | 1,386 | (725) | (136) |
| 1100-1200 | 1,586 | (783) | (202) |
| 1200-1300 | 1,733 | 1,130 | 138 |
| 1300-1400 | 1,796 | 1,140 | 240 |
| 1400-1500 | 1,722 | 990 | 246 |
| 1500-1600 | 1,701 | 1,220 | 205 |
| 1600-1700 | 1,586 | 1,110 | 264 |
| 1700-1800 | 1,691 | 990 | 212 |
| 1800-1900 | 1,407 | 860 | 228 |
| 1900-2000 | (2,560) | 1,000 | 224 |
| 2000-2100 | (2,158) | 860 | 195 |
| 2100-2200 | (1,662) | 620 | 139 |
| 2200-2230 | 567 | 310 | 95 |
| 2230-2300 | 247 | 210 | 39 |
| Total | 23,708 | 13,353 | 2,819 |

Note: Volumes represent two-way counts

Table A-2 (cont). TRAFFIC VOLUMES MEASURED ON ROADWAYS ADJACENT TO THE LIBERTY TREE MALL

ATR SUMMARY SHEET
ADJACENT ROADWAY VOLUMES

December 19, 1973

ATR NO.

| Time of Day | 9<br>Endicott St. | 10<br>Sylvan St. | 11<br>Ash St. |
|---|---|---|---|
| 0800-0900 | 443 | 740 | (126) |
| 0900-1000 | 917 | 840 | (120) |
| 1000-1100 | 1,365 | 870 | 162 |
| 1100-1200 | 1,575 | 940 | (136) |
| 1200-1300 | 1,733 | 1,000 | (234) |
| 1300-1400 | 1,628 | 1,150 | (198) |
| 1400-1500 | 1,796 | 1,100 | 217 |
| 1500-1600 | 1,502 | 1,240 | 486 |
| 1600-1700 | 1,460 | 1,210 | 291 |
| 1700-1800 | 1,586 | 1,170 | 292 |
| 1800-1900 | 1,660 | 1,090 | 298 |
| 1900-2000 | 1,712 | 1,120 | 277 |
| 2000-2100 | 1,570 | 1,000 | 218 |
| 2100-2200 | 1,248 | 780 | 138 |
| 2200-2230 | 536 | 340 | 65 |
| 2230-2300 | 288 | 210 | 30 |
| Total | 21,019 | 14,800 | 3,288 |

Note: Volumes represent two-way counts

Table A-2 (cont). TRAFFIC VOLUMES MEASURED ON ROADWAYS ADJACENT TO THE LIBERTY TREE MALL

ATR SUMMARY SHEET
ADJACENT ROADWAY VOLUMES

December 20, 1973

ATR NO.

| Time of Day | 9<br>Endicott St. | 10<br>Sylvan St. | 11<br>Ash St. |
|---|---|---|---|
| 0800-0900 | 515 | 710 | 107 |
| 0900-1000 | 948 | 760 | 139 |
| 1000-1100 | 1,323 | 860 | 150 |
| 1100-1200 | 1,544 | 890 | 212 |
| 1200-1300 | 1,712 | 1,190 | 243 |
| 1300-1400 | 1,638 | 1,060 | 218 |
| 1400-1500 | 1,523 | 1,130 | 175 |
| 1500-1600 | 1,596 | 1,300 | 312 |
| 1600-1700 | 1,607 | 1,310 | 306 |
| 1700-1800 | 1,785 | 1,320 | 422 |
| 1800-1900 | 1,796 | 1,200 | 273 |
| 1900-2000 | 1,880 | 1,100 | 292 |
| 2000-2100 | 1,827 | 1,100 | 241 |
| 2100-2200 | 1,439 | 780 | 156 |
| 2200-2230 | 546 | 370 | 77 |
| 2230-2300 | 402 | 240 | 47 |
| Total | 22,081 | 15,320 | 3,370 |

Note: Volumes represent two-way counts

Table A-2 (cont). TRAFFIC VOLUMES MEASURED ON ROADWAYS ADJACENT TO THE LIBERTY TREE MALL

ATR SUMMARY SHEET
ADJACENT ROADWAY VOLUMES

December 21, 1973

ATR NO.

| Time of Day | 9 Endicott St. | 10 Sylvan St. | 11 Ash St. |
|---|---|---|---|
| 0800-0900 | 567 | 790 | 140 |
| 0900-1000 | 906 | 1,510 | 170 |
| 1000-1100 | 1,355 | 750 | 179 |
| 1100-1200 | 1,617 | 1,170 | 250 |
| 1200-1300 | 1,659 | 1,080 | 226 |
| 1300-1400 | 1,628 | 1,070 | 206 |
| 1400-1500 | 1,596 | 1,300 | 250 |
| 1500-1600 | 1,754 | 1,390 | 298 |
| 1600-1700 | 1,953 | (1,302) | 350 |
| 1700-1800 | 1,806 | (1,313) | 275 |
| 1800-1900 | 1,743 | (1,192) | 245 |
| 1900-2000 | 2,016 | (1,093) | 224 |
| 2000-2100 | 1,901 | (1,093) | 248 |
| 2100-2200 | 1,197 | (775) | 144 |
| 2200-2230 | 319 | 250 | 35 |
| 2230-2300 | 93 | 260 | 36 |
| Total | 22,107 | 16,338 | 3,276 |

Note: Volumes represent two-way counts

## Table A-2 (cont). TRAFFIC VOLUMES MEASURED ON ROADWAYS ADJACENT TO THE LIBERTY TREE MALL

### ATR SUMMARY SHEET
### ADJACENT ROADWAY VOLUMES

December 22, 1973

ATR NO.

| Time of Day | 9<br>Endicott St. | 10<br>Sylvan St. | 11<br>Ash St. |
|---|---|---|---|
| 0800-0900 | 298 | (486) | 101 |
| 0900-1000 | 876 | (795) | 171 |
| 1000-1100 | 319 | 880 | 263 |
| 1100-1200 | 1,166 | 1,180 | 380 |
| 1200-1300 | 1,964 | 1,220 | 446 |
| 1300-1400 | 2,037 | 1,210 | 461 |
| 1400-1500 | 2,058 | 1,150 | 412 |
| 1500-1600 | 1,891 | 1,110 | 429 |
| 1600-1700 | 1,702 | 960 | 394 |
| 1700-1800 | 1,586 | 830 | 320 |
| 1800-1900 | 1,491 | 660 | 209 |
| 1900-2000 | 1,684 | 630 | 205 |
| 2000-2100 | 1,481 | 670 | 165 |
| 2100-2200 | 1,260 | 460 | 128 |
| 2200-2230 | 422 | 200 | 42 |
| 2230-2300 | 330 | 160 | 43 |
| Total | 20,565 | 12,601 | 4,168 |

Note: Volumes represent two-way counts

Table A-2 (cont). TRAFFIC VOLUMES MEASURED ON ROADWAYS ADJACENT TO THE LIBERTY TREE MALL

ATR SUMMARY SHEET
ADJACENT ROADWAY VOLUMES

December 24, 1973

ATR NO.

| Time of Day | 9 Endicott St. | 10 Sylvan St. | 11 Ash St. |
|---|---|---|---|
| 0800-0900 | 577 | (321) | 160 |
| 0900-1000 | 1,344 | (716) | 300 |
| 1000-1100 | 1,932 | 1,200 | 442 |
| 1100-1200 | 2,016 | (1,057) | 412 |
| 1200-1300 | 2,037 | 1,200 | 510 |
| 1300-1400 | 1,970 | 850 | 477 |
| 1400-1500 | 1,953 | 1,230 | 520 |
| 1500-1600 | 1,796 | 770 | 432 |
| 1600-1700 | 1,386 | 580 | 252 |
| 1700-1800 | 1,134 | 450 | 205 |
| 1800-1900 | | | |
| 1900-2000 | | | |
| 2000-2100 | | | |
| 2100-2200 | | | |
| 2200-2230 | | | |
| 2230-2300 | | | |
| Total | 16,145 | 8,374 | 3,710 |

Note: Volumes represent two-way counts

# APPENDIX B

# RUNNING TIME STUDY DATA

Table B-1 summarizes the hourly data gathered during the Running Time Study portion of the program. Average running times, trip lengths, and number of trips sampled during the hour are given by individual gate and for the shopping center as a whole.

Table B-1. SUMMARY OF HOURLY AVERAGE RUNNING TIME AND TRIP LENGTH BY HOUR OF DAY AND GATE FOR EACH DAY OF THE STUDY PERIOD

COMPILED BY ____

CHECKED BY ____

## COMPLEX SOURCE TRAFFIC STUDY
## LIBERTY TREE MALL, DANVERS, MASSACHUSETTS
## DECEMBER 10 - 24, 1973

DATE 12/10/73

DAY OF WEEK Monday

### RUNNING TIME STUDY — SUMMARY SHEET II

| TIME OF DAY | AVG RUNNING TIME / AVG TRIP LENGTH / NO. OF TRIPS | GATE A |  |  | GATE B |  |  | GATE C |  |  | GATE D |  |  | ALL GATES |  |  |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
|  |  | ARR | DEP | TOT | ARR | DEP | TOT | ARR | DEP | TOT | ARR | DEP | TOT | ARR | DEP | TOT |
| 1000-1100 | AVG. RUN. TIME | 169 | 170 | 339 | 0 | 38 | - | 129 | 88 | 217 | 0 | 110 | - | 150 | 107 | 257 |
|  | AVG. TRIP LENGTH | 0.44 | 0.21 | 0.65 | 0 | 0.30 | - | 0.44 | 1.0 | 1.44 | 0 | 0.70 | - | 0.44 | 0.55 | 0.99 |
|  | NO. OF TRIPS | 8 | 3 | - | 0 | 2 | - | 7 | 3 | - | 0 | 1 | - | 15 | 9 | 26 |
| 1100-1200 | AVG. RUN. TIME | 476 | 162 | 638 | 91 | 88 | 179 | 105 | 0 | - | 130 | 95 | 225 | 140 | 117 | 257 |
|  | AVG. TRIP LENGTH | 1.5 | 0.37 | 1.87 | 0.43 | 0.32 | 0.75 | 0.38 | 0 | - | 0.70 | 0.50 | 1.2 | 0.54 | 0.36 | 0.90 |
|  | NO. OF TRIPS | 1 | 3 | - | 3 | 4 | - | 5 | 0 | - | 1 | 1 | - | 10 | 8 | 18 |
| 1200-1300 | AVG. RUN. TIME | 135 | 78 | 213 | 155 | 106 | 261 | 60 | 74 | 134 | 0 | 126 | - | 127 | 92 | 219 |
|  | AVG. TRIP LENGTH | 0.42 | 0.33 | 0.75 | 0.30 | 0.25 | 0.55 | 0.20 | 0.20 | 0.40 | 0 | 1.0 | - | 0.37 | 0.38 | 0.76 |
|  | NO. OF TRIPS | 5 | 3 | - | 1 | 2 | - | 1 | 1 | - | 0 | 1 | - | 7 | 7 | 14 |
| 1300-1400 | AVG. RUN. TIME | 119 | 157 | 276 | 0 | 102 | - | 109 | 231 | 340 | 0 | 69 | - | 110 | 158 | 268 |
|  | AVG. TRIP LENGTH | 1.0 | 0.30 | 1.30 | 0 | 1.0 | - | 0.49 | 0.75 | 1.24 | 0 | 0.40 | - | 0.55 | 0.51 | 1.06 |
|  | NO. OF TRIPS | 1 | 4 | - | 0 | 1 | - | 8 | 2 | - | 0 | 1 | - | 9 | 8 | 17 |
| 1400-1500 | AVG. RUN. TIME | 161 | 114 | 275 | 114 | 87 | 201 | 125 | 135 | 260 | 122 | 80 | 202 | 133 | 107 | 240 |
|  | AVG. TRIP LENGTH | 0.48 | 0.40 | 0.88 | 0.40 | 0.38 | 0.78 | 0.49 | 0.53 | 1.02 | 0.50 | 0.50 | 1.0 | 0.48 | 0.45 | 0.92 |
|  | NO. OF TRIPS | 4 | 4 | - | 2 | 4 | - | 8 | 4 | - | 1 | 2 | - | 15 | 14 | 29 |
| 1500-1600 | AVG. RUN. TIME | 84 | 140 | 224 | 165 | 83 | 248 | 0 | 85 | - | 82 | 79 | 161 | 85 | 106 | 195 |
|  | AVG. TRIP LENGTH | 0.30 | 0.30 | 0.60 | 0.40 | 0.30 | 0.70 | 0 | 0.20 | - | 0.20 | 0.38 | 0.58 | 0.29 | 0.32 | 0.61 |
|  | NO. OF TRIPS | 12 | 6 | - | 1 | 2 | - | 0 | 1 | - | 3 | 5 | - | 16 | 14 | 30 |
| 1600-1700 | AVG. RUN. TIME | 105 | 101 | 206 | 57 | 78 | 135 | 82 | 60 | 142 | 166 | 60 | 226 | 106 | 86 | 191 |
|  | AVG. TRIP LENGTH | 0.22 | 0.32 | 0.54 | 0.20 | 0.33 | 0.53 | 0.40 | 0.40 | 0.80 | 0.70 | 0.40 | 1.10 | 0.27 | 0.34 | 0.60 |
|  | NO. OF TRIPS | 11 | 6 | - | 1 | 4 | - | 1 | 1 | - | 1 | 1 | - | 14 | 12 | 26 |
| 1700-1800 | AVG. RUN. TIME | 71 | 116 | 187 | 116 | 118 | 234 | 149 | 192 | 341 | 0 | 0 | - | 115 | 132 | 24[illegible] |
|  | AVG. TRIP LENGTH | 0.35 | 0.40 | 0.75 | 0.54 | 0.45 | 0.99 | 0.32 | 0.47 | 0.79 | 0 | 0 | - | 0.43 | 0.43 | 0.86 |
|  | NO. OF TRIPS | 4 | 8 | - | 8 | 4 | - | 5 | 3 | - | 0 | 0 | - | 17 | 15 | 32 |
| 1800-1900 | AVG. RUN. TIME | 115 | 67 | 182 | 84 | 86 | 170 | 105 | 80 | 185 | 110 | 55 | 165 | 106 | 73 | 179 |
|  | AVG. TRIP LENGTH | 0.40 | 0.17 | 0.57 | 0.33 | 0.23 | 0.56 | 0.20 | 0.50 | 0.70 | 0.30 | 0.60 | 0.90 | 0.36 | 0.25 | 0.62 |
|  | NO. OF TRIPS | 10 | 9 | - | 4 | 4 | - | 1 | 2 | - | 1 | 1 | - | 16 | 16 | 32 |
| 1900-2000 | AVG. RUN. TIME | 124 | 160 | 284 | 333 | 66 | 399 | 212 | 202 | 414 | 200 | 50 | 250 | 185 | 128 | 313 |
|  | AVG. TRIP LENGTH | 0.37 | 0.32 | 0.69 | 0.50 | 0.33 | 0.83 | 0.40 | 0.40 | 0.80 | 1.0 | 0.30 | 1.30 | 0.46 | 0.33 | 0.78 |
|  | NO. OF TRIPS | 6 | 6 | - | 2 | 3 | - | 2 | 1 | - | 1 | 1 | - | 11 | 11 | 22 |
| 2000-2100 | AVG. RUN. TIME | 149 | 179 | 328 | 195 | 135 | 330 | 143 | 0 | - | 0 | 0 | - | 165 | 155 | 320 |
|  | AVG. TRIP LENGTH | 0.33 | 0.30 | 0.63 | 0.48 | 0.50 | 0.98 | 0.27 | 0 | - | 0 | 0 | - | 0.38 | 0.41 | 0.79 |
|  | NO. OF TRIPS | 7 | 5 | - | 6 | [illegible] | - | 3 | 0 | - | 0 | 0 | - | 16 | 11 | 27 |
| 2100-2200 | AVG. RUN. TIME | 191 | 123 | 314 | 88 | 62 | 150 | 88 | 128 | 216 | 82 | 63 | 145 | 130 | 106 | 236 |
|  | AVG. TRIP LENGTH | 0.32 | 0.19 | 0.51 | 0.40 | 0.20 | 0.60 | 0.40 | 0.65 | 1.05 | 0.35 | 0.47 | 0.82 | 0.36 | 0.32 | 0.68 |
|  | NO. OF TRIPS | 5 | 8 | - | 2 | 1 | - | 3 | 2 | - | 2 | 3 | - | 12 | 14 | 26 |

FORM T/JP-4

Table B-1 [illegible] SUMMARY OF HOURLY AVERAGE RUNNING TIME AND TRIP LENGTH BY HOUR OF DAY AND GATE FOR EACH DAY OF THE STUDY PERIOD

|  |  |
|---|---|
| COMPILED BY ______ | DATE 12/11/73 |
| CHECKED BY ______ | DAY OF WEEK Tuesday |

## COMPLEX SOURCE TRAFFIC STUDY
## LIBERTY TREE MALL, DANVERS, MASSACHUSETTS
## DECEMBER 10 - 24, 1973

### RUNNING TIME STUDY — SUMMARY SHEET II

| TIME OF DAY | AVG RUNNING TIME (sec) AVG TRIP LENGTH (mi.) NO. OF TRIPS | GATE A |  |  | GATE B |  |  | GATE C |  |  | GATE D |  |  | ALL GATES |  |  |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
|  |  | ARR | DEP | TOT | ARR | DEP | TOT | ARR | DEP | TOT | ARR | DEP | TOT | ARR | DEP | TOT |
| 1000-1100 | AVG. RUN. TIME | 119 | 112 | 231 | 0 | 73 | - | 0 | 0 | - | 72 | 0 | - | 106 | 99 | 205 |
|  | AVG. TRIP LENGTH | 0.38 | C.50 | 0.88 | 0 | 0.10 | - | 0 | 0 | - | 0.80 | 0 | - | 0.50 | 0.37 | 0.87 |
|  | NO. OF TRIPS | 5 | 4 | - | 0 | 2 | - | 0 | 0 | - | 2 | 0 | - | 7 | 6 | 13 |
| 1100-1200 | AVG. RUN. TIME | 164 | 68 | 232 | 129 | 91 | 220 | 114 | 95 | 214 | 0 | 0 | - | 142 | 88 | 230 |
|  | AVG. TRIP LENGTH | 0.35 | 0.25 | 0.60 | 0.28 | 0.27 | 0.55 | 0.47 | 0.38 | 0.85 | 0 | 0 | - | 0.36 | 0.30 | 0.66 |
|  | NO. OF TRIPS | 6 | 2 | - | 4 | 6 | - | 3 | 4 | - | 0 | 0 | - | 13 | 12 | 25 |
| 1200-1300 | AVG. RUN. TIME | 137 | 99 | 236 | 113 | 131 | 244 | 141 | 102 | 243 | 159 | 92 | 251 | 134 | 109 | 243 |
|  | AVG. TRIP LENGTH | 0.48 | 0.28 | 0.76 | 0.38 | 0.40 | 0.78 | 0.43 | 0.50 | 0.93 | 0.95 | 0.40 | 1.35 | 0.51 | 0.36 | 0.87 |
|  | NO. OF TRIPS | 4 | 5 | - | 4 | 4 | - | 3 | 1 | - | 2 | 2 | - | 13 | 12 | 25 |
| 1300-1400 | AVG. RUN. TIME | 100 | 101 | 201 | 66 | 106 | 172 | 82 | 99 | 181 | 0 | 0 | - | 95 | 104 | 199 |
|  | AVG. TRIP LENGTH | 0.35 | 0.33 | 0.68 | 0.30 | 0.34 | 0.64 | 0.70 | 0.20 | 0.90 | 0 | 0 | - | 0.36 | 0.33 | 0.69 |
|  | NO. OF TRIPS | 14 | 4 | - | 2 | 11 | - | 1 | 1 | - | 0 | 0 | - | 17 | 16 | 33 |
| 1400-1500 | AVG. RUN. TIME | 107 | 67 | 174 | 85 | 164 | 249 | 118 | 116 | 234 | 72 | 128 | 200 | 103 | 86 | 189 |
|  | AVG. TRIP LENGTH | 0.37 | 0.30 | 0.67 | 0.35 | [illegible] | 0.85 | 0.43 | 0.30 | 0.73 | 0.40 | 0.40 | 0.80 | 0.38 | 0.33 | 0.70 |
|  | NO. OF TRIPS | 10 | 8 | - | 2 | [illegible] | - | 2 | 1 | - | 1 | 1 | - | 15 | 11 | 26 |
| 1500-1600 | AVG. RUN. TIME | 105 | 115 | 220 | 128 | 119 | 247 | 375 | 156 | 531 | 60 | 139 | 199 | 126 | 120 | 246 |
|  | AVG. TRIP LENGTH | 0.36 | 0.34 | 0.70 | 0.43 | 0.40 | 0.83 | 0.60 | 0.40 | 1.00 | 0.40 | 0.90 | 1.30 | 0.60 | 0.40 | 0.79 |
|  | NO. OF TRIPS | 9 | 9 | - | 3 | 4 | - | 1 | 1 | - | 1 | 1 |  | 14 | 15 | 29 |
| 1600-1700 | AVG. RUN. TIME | 76 | 107 | 183 | 93 | 91 | 184 | 0 | 0 | - | 0 | 39 | - | 90 | 93 | 182 |
|  | AVG. TRIP LENGTH | 0.20 | 0.24 | 0.44 | 0.41 | 0.33 | 0.74 | 0 | 0 | - | 0 | 0.20 | - | 0.37 | 0.29 | 0.66 |
|  | NO. OF TRIPS | 3 | 5 | - | 12 | 10 | - | 0 | 0 | - | 0 | 1 | - | 15 | 16 | 31 |
| 1700-1800 | AVG. RUN. TIME | 90 | 101 | 191 | 103 | 78 | 181 | 0 | 0 | - | 101 | 119 | 220 | 99 | 91 | 190 |
|  | AVG. TRIP LENGTH | 0.32 | 0.22 | 0.54 | 0.36 | 0.26 | 0.62 | 0 | 0 | - | 0.35 | 0.40 | 0.75 | 0.35 | 0.25 | 0.60 |
|  | NO. OF TRIPS | 5 | 6 | - | 10 | 7 | - | 0 | 0 | - | 2 | 1 | - | 17 | 14 | 31 |
| 1800-1900 | AVG. RUN. TIME | 138 | 110 | 268 | 96 | 86 | 180 | 112 | 163 | 275 | 78 | 89 | 167 | 107 | 110 | 217 |
|  | AVG. TRIP LENGTH | 0.52 | 0.35 | 0.87 | 0.33 | 0.30 | 0.63 | 0.48 | 0.35 | 0.83 | 0.35 | 0.33 | 0.68 | 0.43 | 0.34 | 0.76 |
|  | NO. OF TRIPS | 5 | 6 | - | 4 | 2 | - | 4 | 2 | - | 4 | 3 | - | 17 | 13 | 30 |
| 1900-2000 | AVG. RUN. TIME | 182 | 77 | 259 | 127 | 123 | 250 | 108 | 118 | 226 | 122 | 136 | 258 | 150 | 120 | 269 |
|  | AVG. TRIP LENGTH | 0.46 | 0.20 | 0.66 | 0.40 | 0.33 | 0.73 | 0.10 | 0.50 | 0.60 | 0.50 | 0.50 | 1.00 | 0.41 | 0.35 | 0.76 |
|  | NO. OF TRIPS | 5 | 1 | - | 4 | 8 | - | 1 | 1 | - | 1 | 1 | - | 11 | 11 | 22 |
| 2000-2100 | AVG. RUN. TIME | 124 | 207 | 231 | 162 | 135 | 297 | 206 | 106 | 312 | 245 | 0 | - | 156 | 149 | 305 |
|  | AVG. TRIP LENGTH | 0.36 | 0.40 | 0.76 | 0.30 | 0.38 | 0.68 | 0.40 | 0.20 | 0.60 | 1.0 | 0 | - | 0.41 | 0.36 | 0.77 |
|  | NO. OF TRIPS | 5 | 2 |  | 3 | 5 | - | 1 | 1 | - | 1 | 0 | - | 10 | 8 | 18 |
| 2100-2200 | AVG. RUN. TIME | 101 | 135 | 326 | 145 | 133 | 278 | 122 | 101 | 223 | 86 | 119 | 205 | 112 | 126 | 238 |
|  | AVG. TRIP LENGTH | 0.22 | 0.23 | 0.45 | 0.28 | 0.30 | 0.58 | 0.40 | 0.40 | 0.80 | 0.73 | 0.53 | 1.26 | 0.33 | 0.35 | 0.68 |
|  | NO. OF TRIPS | 9 | 4 | - | 5 | 2 | - | 1 | 1 | - | 3 | 3 | - | 18 | 10 | 28 |

FORM [illegible]

Table B-1 (Cont). SUMMARY OF HOURLY AVERAGE RUNNING TIME AND TRIP LENGTH BY HOUR OF DAY AND GATE FOR EACH DAY OF THE STUDY PERIOD

COMPILED BY ________

CHECKED BY ________

## COMPLEX SOURCE TRAFFIC STUDY
## LIBERTY TREE MALL, DANVERS, MASSACHUSETTS
## DECEMBER 10 - 24, 1973

DATE 12/12/73

DAY OF WEEK Wednesday

### RUNNING TIME STUDY — SUMMARY SHEET II

| TIME OF DAY | AVG RUNNING TIME(sec)<br>AVG TRIP LENGTH(miles)<br>NO. OF TRIPS | GATE A | | | GATE B | | | GATE C | | | GATE D | | | ALL GATES | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | ARR | DEP | TOT | ARR | DEP | TOT | ARR | DEP | TOT | ARR | DEP | TOT | ARR | DEP | TOT |
| 1000-1100 | AVG. RUN. TIME | 120 | 110 | 230 | 88 | 114 | 202 | 112 | 122 | 236 | 147 | 193 | 340 | 123 | 138 | 261 |
| | AVG. TRIP LENGTH | 0.38 | 0.46 | 0.84 | 0.40 | 0.20 | 0.60 | 0.30 | 0.35 | 0.65 | 0.52 | 0.60 | 1.12 | 0.41 | 0.45 | 0.86 |
| | NO. OF TRIPS | 6 | 5 | - | 2 | 2 | - | 3 | 2 | - | 5 | 4 | - | 16 | 13 | 29 |
| 1100-1200 | AVG. RUN. TIME | 147 | 120 | 267 | 145 | 118 | 263 | 99 | 99 | 198 | 0 | 0 | - | 122 | 113 | 235 |
| | AVG. TRIP LENGTH | 0.40 | 0.36 | 0.76 | 0.57 | 0.53 | 1.10 | 0.34 | 0.30 | 0.64 | 0 | 0 | - | 0.44 | 0.39 | 0.84 |
| | NO. OF TRIPS | 1 | 5 | - | 6 | 4 | - | 7 | 4 | - | 0 | 0 | - | 14 | 13 | 27 |
| 1200-1300 | AVG. RUN. TIME | 114 | 71 | 185 | 203 | 104 | 307 | 32 | 61 | 93 | 0 | 127 | - | 143 | 87 | 230 |
| | AVG. TRIP LENGTH | 0.26 | 0.26 | 0.52 | 0.61 | 0.35 | 0.96 | 0.13 | 0.40 | 0.53 | 0 | 0.60 | - | 0.41 | 0.33 | 0.74 |
| | NO. OF TRIPS | 5 | 7 | - | 8 | 6 | - | 3 | 1 | - | 0 | 1 | - | 16 | 15 | 31 |
| 1300-1400 | AVG. RUN. TIME | 102 | 109 | 211 | 157 | 95 | 252 | 46 | 129 | 175 | 92 | 71 | 163 | 116 | 105 | 221 |
| | AVG. TRIP LENGTH | 0.33 | 0.24 | 0.57 | 0.32 | 0.25 | 0.57 | 0.20 | 0.45 | 0.65 | 0.40 | 0.20 | 0.60 | 0.32 | 0.27 | 0.59 |
| | NO. OF TRIPS | 8 | 7 | - | 5 | 4 | - | 1 | 2 | - | 1 | 1 | - | 15 | 14 | 29 |
| 1400-1500 | AVG. RUN. TIME | 144 | 94 | 238 | 116 | 110 | 226 | 104 | 132 | 236 | 0 | 78 | - | 120 | 99 | 218 |
| | AVG. TRIP LENGTH | 0.38 | 0.22 | 0.60 | 0.32 | 0.40 | 0.72 | 0.38 | 0.45 | 0.83 | 0 | 0.45 | - | 0.36 | 0.30 | 0.66 |
| | NO. OF TRIPS | 4 | 10 | - | 5 | 2 | - | 5 | 2 | - | 0 | 2 | - | 14 | 16 | 30 |
| 1500-1600 | AVG. RUN TIME | 102 | 119 | 221 | 139 | 118 | 257 | 102 | 62 | 164 | 132 | 88 | 220 | 118 | 107 | 225 |
| | AVG. TRIP LENGTH | 0.28 | 0.27 | 0.55 | 0.40 | 0.33 | 0.73 | 0.40 | 0.40 | 0.80 | 0.77 | 0.40 | 1.17 | 0.43 | 0.33 | 0.76 |
| | NO. OF TRIPS | 5 | 6 | - | 5 | 4 | - | 4 | 1 | - | 3 | 4 | - | 17 | 15 | 32 |
| 1600-1700 | AVG. RUN. TIME | 124 | 153 | 277 | 0 | 0 | - | 100 | 109 | 209 | 117 | 150 | 267 | 117 | 140 | 257 |
| | AVG. TRIP LENGTH | 0.34 | 0.40 | 0.74 | 0 | 0 | - | 0.33 | 0.50 | 0.83 | 0.30 | 0.80 | 101 | 0.33 | 0.46 | 0.79 |
| | NO. OF TRIPS | 9 | 9 | - | 0 | 0 | - | 4 | 4 | - | 1 | 1 | - | 14 | 14 | 28 |
| 1700-1800 | AVG. RUN TIME | 138 | 94 | 232 | 98 | 98 | 196 | 150 | 0 | - | 165 | 81 | 246 | 124 | 90 | 214 |
| | AVG. TRIP LENGTH | 0.32 | 0.26 | 0.58 | 0.28 | 0.30 | 0.58 | 0.20 | 0 | - | 0.20 | 0.36 | 0.56 | 0.29 | 0.29 | 0.58 |
| | NO. OF TRIPS | 6 | 10 | - | 6 | 1 | - | 1 | 0 | - | 1 | 5 | - | 16 | 16 | 30 |
| 1800-1900 | AVG. RUN TIME | 116 | 123 | 239 | 110 | 100 | 210 | 59 | 131 | 190 | 51 | 305 | 356 | 92 | 131 | 222 |
| | AVG. TRIP LENGTH | 0.27 | 0.36 | 0.63 | 0.42 | 0.30 | 0.72 | 0.37 | 0.40 | 0.77 | 0.25 | 0.20 | 0.45 | 0.35 | 0.33 | 0.68 |
| | NO. OF TRIPS | 3 | 7 | - | 6 | 4 | - | 3 | 1 | - | 2 | 1 | - | 14 | 13 | 27 |
| 1900-2000 | AVG. RUN. TIME | 195 | 119 | 316 | 225 | 113 | 338 | 187 | 137 | 324 | 0 | 110 | - | 205 | 118 | 324 |
| | AVG. TRIP LENGTH | 0.40 | 0.31 | 0.71 | 0.42 | 0.27 | 0.79 | 0.50 | 0.10 | 0.60 | 0 | 0.60 | - | 0.46 | 0.31 | 0.77 |
| | NO. OF TRIPS | 6 | 9 | - | 5 | 3 | - | 2 | 1 | - | 0 | 1 | - | 13 | 14 | 27 |
| 2000-2100 | AVG. RUN. TIME | 201 | 90 | 291 | 204 | 115 | 319 | 0 | 0 | - | 0 | 0 | - | 202 | 95 | 297 |
| | AVG. TRIP LENGTH | 0.40 | 0.19 | 0.59 | 0.43 | 0.25 | 0.68 | 0 | 0 | - | 0 | 0 | - | 0.41 | 0.20 | 0.61 |
| | NO. OF TRIPS | 6 | 8 | - | 3 | 2 | - | 0 | 0 | - | 0 | 0 | - | 9 | 10 | 19 |
| 2100-2200 | AVG. RUN TIME | 101 | 114 | 215 | 95 | 47 | 142 | 124 | 109 | 233 | 0 | 60 | - | 102 | 96 | 197 |
| | AVG. TRIP LENGTH | 0.40 | 0.23 | 0.63 | 0.32 | 0.23 | 0.55 | 0.45 | 0.28 | 0.73 | 0 | 0.1 | - | 0.37 | 0.24 | 0.61 |
| | NO. OF TRIPS | 6 | 7 | - | 6 | 3 | - | 2 | 4 | - | 0 | 1 | - | 14 | 15 | 29 |

FORM T/JP-4

Table B-1 ( SUMMARY OF HOURLY AVERAGE RUNNING TIME AND TRIP LENGTH BY HOUR OF DAY AND GATE FOR EACH DAY OF THE STUDY PERIOD

COMPILED BY ________

CHECKED BY ________

## COMPLEX SOURCE TRAFFIC STUDY
## LIBERTY TREE MALL, DANVERS, MASSACHUSETTS
## DECEMBER 10 - 24, 1973

DATE 12/13/73

DAY OF WEEK Thursday

### RUNNING TIME STUDY — SUMMARY SHEET II

| TIME OF DAY | AVG RUNNING TIME (sec) AVG TRIP LENGTH (miles) NO. OF TRIPS | GATE A | | | GATE B | | | GATE C | | | GATE D | | | ALL GATES | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | ARR | DEP | TOT | ARR | DEP | TOT | ARR | DEP | TOT | ARR | DEP | TOT | ARR | DEP | TOT |
| 1000-1100 | AVG. RUN. TIME | 70 | 129 | 199 | 103 | 99 | 202 | 102 | 144 | 246 | 97 | 92 | 189 | 91 | 114 | 205 |
| | AVG. TRIP LENGTH | 0.35 | 0.30 | 0.65 | 0.42 | 0.23 | 0.65 | 0.35 | 0.35 | 0.70 | 0.48 | 0.48 | 0.96 | 0.41 | 0.33 | 0.74 |
| | NO. OF TRIPS | 6 | 6 | - | 6 | 4 | - | 2 | 2 | - | 5 | 4 | - | 19 | 16 | 35 |
| 1100-1200 | AVG. RUN. TIME | 89 | 98 | 187 | 120 | 84 | 204 | 113 | 107 | 220 | 117 | 133 | 250 | 111 | 102 | 212 |
| | AVG. TRIP LENGTH | 0.58 | 0.32 | 0.90 | 0.35 | 0.44 | 0.79 | 0.47 | 0.30 | 0.77 | 0.60 | 0.60 | 1.20 | 0.48 | 0.41 | 0.90 |
| | NO. OF TRIPS | 4 | 5 | - | 6 | 5 | - | 3 | 2 | - | 4 | 3 | - | 17 | 15 | 32 |
| 1200-1300 | AVG. RUN. TIME | 91 | 95 | 186 | 100 | 83 | 183 | 131 | 138 | 269 | 80 | 135 | 215 | 105 | 99 | 204 |
| | AVG. TRIP LENGTH | 0.40 | 0.24 | 0.64 | 0.40 | 0.18 | 0.58 | 0.38 | 0.40 | 0.78 | 0.60 | 0.80 | 1.40 | 0.41 | 0.28 | 0.68 |
| | NO. OF TRIPS | 3 | 5 | - | 7 | 6 | - | 4 | 2 | - | 1 | 1 | - | 15 | 14 | 29 |
| 1300-1400 | AVG. RUN. TIME | 82 | 117 | 199 | 119 | 0 | - | 154 | 120 | 274 | 117 | 88 | 205 | 105 | 113 | 217 |
| | AVG. TRIP LENGTH | 0.31 | 0.28 | 0.59 | 0.47 | 0 | - | 0.47 | 0.37 | 0.84 | 0.40 | 0.37 | 0.77 | 0.38 | 0.31 | 0.66 |
| | NO. OF TRIPS | 10 | 12 | - | 3 | 0 | - | 3 | 3 | - | 3 | 3 | - | 19 | 16 | 37 |
| 1400-1500 | AVG. RUN. TIME | 93 | 80 | 173 | 141 | 0 | - | 100 | 183 | 283 | 0 | 47 | - | 99 | 103 | 203 |
| | AVG. TRIP LENGTH | 0.34 | 0.29 | 0.63 | 0.50 | 0 | - | 0.33 | 0.40 | 0.73 | 0 | 0.20 | - | 0.34 | 0.31 | 0.65 |
| | NO. OF TRIPS | 7 | 9 | - | 1 | 0 | - | 8 | 4 | - | 0 | 2 | - | 16 | 15 | 31 |
| 1500-1600 | AVG. RUN. TIME | 110 | 142 | 252 | 98 | 97 | 195 | 119 | 165 | 284 | 88 | 88 | 176 | 103 | 106 | 210 |
| | AVG. TRIP LENGTH | 0.30 | 0.40 | 0.70 | 0.40 | 0.45 | 0.85 | 0.50 | 0.50 | 1.00 | 0.35 | 0.40 | 0.75 | 0.38 | 0.43 | 0.81 |
| | NO. OF TRIPS | 4 | 3 | - | 2 | 6 | - | 4 | 1 | - | 6 | 5 | - | 16 | 15 | 31 |
| 1600-1700 | AVG. RUN. TIME | 169 | 97 | 266 | 105 | 130 | 235 | 165 | 124 | 289 | 91 | 98 | 189 | 136 | 112 | 250 |
| | AVG. TRIP LENGTH | 0.40 | 0.23 | 0.63 | 0.38 | 0.30 | 0.68 | 0.48 | 0.53 | 1.03 | 0.45 | 0.40 | 0.85 | 0.42 | 0.34 | 0.76 |
| | NO. OF TRIPS | 6 | 6 | - | 6 | 4 | - | 4 | 4 | - | 2 | 2 | - | 18 | 16 | 34 |
| 1700-1800 | AVG. RUN. TIME | 131 | 70 | 201 | 93 | 84 | 177 | 97 | 62 | 159 | 114 | 122 | 236 | 106 | 95 | 202 |
| | AVG. TRIP LENGTH | 0.60 | 0.23 | 0.83 | 0.43 | 0.20 | 0.63 | 0.30 | 0.17 | 0.47 | 0.52 | 0.40 | 0.92 | 0.44 | 0.30 | 0.74 |
| | NO. OF TRIPS | 2 | 3 | - | 3 | 1 | - | 5 | 3 | - | 5 | 7 | - | 15 | 14 | 29 |
| 1800-1900 | AVG. RUN. TIME | 105 | 123 | 228 | 155 | 120 | 275 | 40 | 125 | 165 | 0 | 30 | - | 114 | 112 | 226 |
| | AVG. TRIP LENGTH | 0.38 | 0.26 | 0.64 | 0.54 | 0.60 | 1.14 | 0.35 | 0.20 | 0.55 | 0 | 0.20 | - | 0.44 | 0.32 | 0.76 |
| | NO. OF TRIPS | 6 | 5 | - | 5 | 2 | - | 2 | 1 | - | 0 | 1 | - | 13 | 9 | 22 |
| 1900-2000 | AVG. RUN. TIME | 177 | 147 | 324 | 159 | 154 | 313 | 0 | 0 | - | 126 | 98 | 224 | 158 | 132 | 290 |
| | AVG. TRIP LENGTH | 0.48 | 0.38 | 0.86 | 0.50 | 0.45 | 0.95 | 0 | 0 | - | 0.57 | 0.48 | 1.05 | 0.51 | 0.42 | 0.94 |
| | NO. OF TRIPS | 5 | 6 | - | 2 | 2 | - | 0 | 0 | - | 3 | 4 | | 10 | 12 | 22 |
| 2000-2100 | AVG. RUN. TIME | 97 | 96 | 193 | 158 | 178 | 326 | 141 | 161 | 302 | 332 | 97 | 429 | 157 | 117 | 274 |
| | AVG. TRIP LENGTH | 0.25 | 0.30 | 0.55 | 0.55 | 0.60 | 1.15 | 0.48 | 0.60 | 1.08 | 0.60 | 0.37 | 0.97 | 0.48 | 0.40 | 0.88 |
| | NO. OF TRIPS | 2 | 5 | - | 4 | 2 | - | 4 | 1 | - | 1 | 3 | | 11 | 11 | 22 |
| 2100-2200 | AVG. RUN. TIME | 91 | 148 | 239 | 63 | 43 | 106 | 72 | 35 | 107 | 196 | 0 | - | 99 | 100 | 199 |
| | AVG. TRIP LENGTH | 0.40 | 0.38 | 0.68 | 0.25 | 0.15 | 0.40 | 0.33 | 0.30 | 0.63 | 0.80 | 0 | - | 0.42 | 0.26 | 0.68 |
| | NO. OF TRIPS | 5 | 5 | - | 2 | 2 | - | 3 | 2 | - | 2 | 0 | - | 12 | 4 | 21 |

FORM T/UP-4

Table B-1 (Cont). SUMMARY OF HOURLY AVERAGE RUNNING TIME AND TRIP LENGTH BY HOUR OF DAY AND GATE FOR EACH DAY OF THE STUDY PERIOD

COMPILED BY ____

CHECKED BY ____

## COMPLEX SOURCE TRAFFIC STUDY
## LIBERTY TREE MALL, DANVERS, MASSACHUSETTS
## DECEMBER 10 - 24, 1973

DATE 12/14/73

DAY OF WEEK Friday

### RUNNING TIME STUDY — SUMMARY SHEET II

| TIME OF DAY | AVG RUNNING TIME and AVG TRIP LENGTH and NO. OF TRIPS | GATE A |  |  | GATE B |  |  | GATE C |  |  | GATE D |  |  | ALL GATES |  |  |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
|  |  | ARR | DEP | TOT | ARR | DEP | TOT | ARR | DEP | TOT | ARR | DEP | TOT | ARR | DEP | TOT |
| 1000-1100 | AVG. RUN. TIME | 119 | 108 | 227 | 171 | 129 | 300 | 137 | 103 | 240 | 108 | 192 | 300 | 143 | 122 | 266 |
|  | AVG TRIP LENGTH | 0.40 | 0.23 | 0.63 | 0.46 | 0.28 | 0.74 | 0.34 | 0.37 | 0.71 | 0.50 | 0.90 | 1.40 | 0.41 | 0.34 | 0.75 |
|  | NO OF TRIPS | 3 | 3 |  | 5 | 5 | - | 5 | 3 | - | 1 | 1 | - | 14 | 12 | 26 |
| 1100-1200 | AVG. RUN. TIME | 126 | 105 | 231 | 138 | 96 | 234 | 136 | 164 | 300 | 88 | 99 | 187 | 128 | 117 | 245 |
|  | AVG TRIP LENGTH | 0.42 | 0.16 | 0.58 | 0.32 | 0.28 | 0.60 | 0.43 | 0.53 | 0.96 | 0.35 | 0.30 | 0.65 | 0.38 | 0.29 | 0.67 |
|  | NO. OF TRIPS | 5 | 7 | - | 5 | 4 | - | 4 | 4 | - | 2 | 1 | - | 16 | 16 | 32 |
| 1200-1300 | AVG. RUN TIME | 117 | 87 | 204 | 136 | 84 | 220 | 164 | 147 | 311 | 188 | 101 | 289 | 156 | 111 | 267 |
|  | AVG TRIP LENGTH | 0.30 | 0.20 | 0.50 | 0.40 | 0.25 | 0.65 | 0.64 | 0.40 | 1.04 | 0.50 | 0.38 | 0.88 | 0.50 | 0.36 | 0.85 |
|  | NO. OF TRIPS | 1 | 1 |  | 5 | 2 |  | 5 | 4 | - | 3 | 6 | - | 14 | 13 | 27 |
| 1300-1400 | AVG. RUN. TIME | 106 | 119 | 225 | 111 | 136 | 247 | 176 | 353 | 529 | - | - | - | 117 | 141 | 258 |
|  | AVG. TRIP LENGTH | 0.33 | 0.33 | 0.66 | 0.23 | 0.25 | 0.48 | 0.55 | 0.30 | 0.83 | - | - | - | 0.33 | 0.30 | 0.64 |
|  | NO OF TRIPS | 8 | 9 |  | 4 | 4 | - | 2 | 1 | - | - | - | - | 14 | 14 | 28 |
| 1400-1500 | AVG. RUN TIME | 113 | 128 | 241 | 147 | 136 | 283 | 112 | 490 | 602 | 100 | 198 | 298 | 114 | 186 | 299 |
|  | AVG. TRIP LENGTH | 0.48 | 0.38 | 0.86 | 0.60 | 0.10 | 0.70 | 0.13 | 0.90 | 1.03 | 0.50 | 0.63 | 1.13 | 0.39 | 0.48 | 0.87 |
|  | NO. OF TRIPS | 4 | 5 | - | 1 | 1 | - | 3 | 1 | - | 2 | 3 | - | 10 | 10 | 20 |
| 1500-1600 | AVG. RUN TIME | 80 | 140 | 220 | 128 | 103 | 231 | 116 | 172 | 288 | 272 | 90 | 362 | 104 | 132 | 236 |
|  | AVG. TRIP LENGTH | 0.25 | 0.38 | 0.63 | 0.30 | 0.28 | 0.58 | 0.50 | 0.45 | 0.95 | 0.40 | 0.30 | 0.70 | 0.30 | 0.36 | 0.66 |
|  | NO. OF TRIPS | 11 | 10 | - | 3 | 4 | - | 2 | 2 | - | 1 | 1 | - | 17 | 17 | 34 |
| 1600-1700 | AVG. RUN TIME | 103 | 124 | 227 | 111 | 110 | 221 | 108 | 206 | 314 | 181 | 68 | 249 | 113 | 130 | 242 |
|  | AVG. TRIP LENGTH | 0.38 | 0.28 | 0.66 | 0.43 | 0.33 | 0.76 | 0.30 | 0.37 | 0.67 | 0.60 | 0.45 | 1.05 | 0.39 | 0.34 | 0.73 |
|  | NO. OF TRIPS | 4 | 5 | - | 6 | 4 | - | 4 | 3 | - | 1 | 2 | - | 15 | 14 | 29 |
| 1700-1800 | AVG. RUN TIME | 100 | 134 | 234 | 93 | 114 | 207 | 154 | 88 | 242 | 271 | 88 | 359 | 117 | 119 | 237 |
|  | AVG. TRIP LENGTH | 0.33 | 0.29 | 0.62 | 0.33 | 0.23 | 0.56 | 0.40 | 0.20 | 0.60 | 0.60 | 0.30 | 0.90 | 0.36 | 0.27 | 0.63 |
|  | NO. OF TRIPS | 9 | 8 | - | 3 | 4 | - | 2 | 1 | - | 1 | 2 | - | 15 | 15 | 30 |
| 1800-1900 | AVG. RUN TIME | 155 | 98 | 253 | 115 | 160 | 275 | 129 | 127 | 256 | 105 | 175 | 280 | 137 | 119 | 256 |
|  | AVG. TRIP LENGTH | 0.38 | 0.34 | 0.72 | 0.30 | 0.30 | 0.60 | 0.39 | 0.43 | 0.82 | 0.40 | 0.90 | 1.30 | 0.38 | 0.41 | 0.79 |
|  | NO. OF TRIPS | 6 | 7 | - | 1 | 1 | - | 7 | 7 | - | 1 | 1 | - | 15 | 16 | 31 |
| 1900-2000 | AVG. RUN TIME | 152 | 73 | 225 | - | 81 | - | 185 | 55 | 240 | 238 | 151 | 389 | 180 | 88 | 268 |
|  | AVG. TRIP LENGTH | 0.34 | 0.13 | 0.47 | - | 0.20 | - | 0.40 | 0.15 | 0.55 | 0.75 | 0.40 | 1.15 | 0.44 | 0.22 | 0.65 |
|  | NO. OF TRIPS | 5 | 3 | - | - | 1 | - | 4 | 4 | - | 2 | 3 | - | 11 | 11 | 22 |
| 2000-2100 | AVG. RUN TIME | 181 | 293 | 474 | 106 | 172 | 278 | 184 | 105 | 289 | - | - | - | 167 | 211 | 378 |
|  | AVG. TRIP LENGTH | 0.36 | 0.38 | 0.74 | 0.35 | 0.27 | 0.62 | 0.43 | 0.35 | 0.78 | - | - | - | 0.38 | 0.34 | 0.72 |
|  | NO. OF TRIPS | 5 | 4 | - | 2 | 3 | - | 3 | 2 | - | - | - | - | 10 | 9 | 19 |
| 2100-2200 | AVG. RUN TIME | 135 | 110 | 245 | 127 | 160 | 287 | 98 | 288 | 386 | 112 | 155 | 267 | 125 | 156 | 280 |
|  | AVG. TRIP LENGTH | 0.28 | 0.30 | 0.58 | 0.40 | 0.40 | 0.80 | 0.20 | 0.75 | 0.95 | 0.60 | 0.65 | 1.25 | 0.38 | 0.45 | 0.83 |
|  | NO. OF TRIPS | 4 | 6 | - | 4 | 3 | - | 1 | 2 | 0 | 2 | 2 | - | 11 | 11 | 22 |

FORM T/JP-4

Table B-1 (Cont.) SUMMARY OF HOURLY AVERAGE RUNNING TIME AND TRIP LENGTH BY HOUR OF DAY AND GATE FOR EACH DAY OF THE STUDY PERIOD

COMPILED BY ________

CHECKED BY ________

## COMPLEX SOURCE TRAFFIC STUDY
## LIBERTY TREE MALL, DANVERS, MASSACHUSETTS
## DECEMBER 10 - 24, 1973

DATE 12/15/73

DAY OF WEEK Saturday

### RUNNING TIME STUDY — SUMMARY SHEET II

| TIME OF DAY | AVG RUNNING TIME<br>AVG TRIP LENGTH<br>NO. OF TRIPS | GATE A | | | GATE B | | | GATE C | | | GATE D | | | ALL GATES | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | ARR | DEP | TOT | ARR | DEP | TOT | ARR | DEP | TOT | ARR | DEP | TOT | ARR | DEP | TOT |
| 1000-1100 | AVG. RUN. TIME | 134 | 126 | 260 | 70 | 85 | 155 | 94 | 132 | 226 | 132 | 91 | 223 | 112 | 118 | 230 |
| | AVG. TRIP LENGTH | 0.36 | 0.21 | 0.57 | 0.15 | 0.10 | 0.25 | 0.38 | 0.60 | 0.98 | 0.55 | 0.35 | 0.90 | 0.36 | 0.28 | 0.65 |
| | NO. OF TRIPS | 5 | 8 | - | 2 | 1 | - | 4 | 2 | - | 2 | 2 | - | 13 | 13 | 26 |
| 1100-1200 | AVG. RUN. TIME | 103 | 142 | 245 | 96 | 102 | 198 | 156 | - | - | 80 | 95 | 175 | 111 | 117 | 228 |
| | AVG. TRIP LENGTH | 0.30 | 0.27 | 0.57 | 0.30 | 0.40 | 0.70 | 0.23 | - | - | 0.30 | 0.45 | 0.75 | 0.28 | 0.36 | 0.64 |
| | NO. OF TRIPS | 6 | 6 | - | 2 | 4 | - | 3 | - | - | 2 | 4 | - | 13 | 14 | 27 |
| 200-300 | AVG. RUN. TIME | 226 | 417 | 643 | 109 | 148 | 257 | 113 | 206 | 319 | 181 | 90 | 271 | 150 | 246 | 395 |
| | AVG. TRIP LENGTH | 0.63 | 0.48 | 1.11 | 0.50 | 0.34 | 0.84 | 0.42 | 0.70 | 1.12 | 0.80 | 0.40 | 1.20 | 0.52 | 0.43 | 0.95 |
| | NO. OF TRIPS | 3 | 4 | - | 1 | 5 | - | 6 | 1 | - | 1 | 1 | - | 11 | 11 | 22 |
| 300-400 | AVG. RUN. TIME | 433 | 472 | 905 | 198 | 148 | 346 | 86 | 85 | 171 | - | - | - | 201 | 232 | 432 |
| | AVG. TRIP LENGTH | 0.50 | 0.30 | 0.80 | 0.40 | 0.50 | 0.90 | 0.68 | 0.30 | 0.98 | - | - | - | 0.56 | 0.41 | 0.98 |
| | NO. OF TRIPS | 2 | 2 | - | 2 | 4 | - | 4 | 1 | - | - | - | - | 8 | 7 | 15 |
| 400-500 | AVG. RUN. TIME | 138 | - | - | 244 | 202 | 446 | 149 | 452 | 601 | 128 | 120 | 248 | 185 | 265 | 450 |
| | AVG. TRIP LENGTH | 0.40 | - | - | 0.43 | 0.60 | 1.03 | 0.65 | 0.60 | 1.25 | 0.50 | 0.47 | 0.97 | 0.49 | 0.55 | 1.04 |
| | NO. OF TRIPS | 1 | - | - | 4 | 2 | - | 2 | 3 | - | 2 | 3 | - | 9 | 8 | 17 |
| 500-600 | AVG. RUN. TIME | 211 | 267 | 478 | - | 70 | - | 248 | 160 | 408 | - | 124 | - | 232 | 217 | 450 |
| | AVG. TRIP LENGTH | 0.33 | 0.27 | 0.60 | - | 0.20 | - | 0.40 | 0.70 | 1.10 | - | 0.40 | - | 0.37 | 0.32 | 0.69 |
| | NO. OF TRIPS | 3 | 6 | - | - | 1 | - | 4 | 1 | - | - | 1 | - | 7 | 9 | 16 |
| 600-700 | AVG. RUN. TIME | 181 | 221 | 402 | 107 | 138 | 245 | 99 | 105 | 204 | - | - | - | 124 | 165 | 289 |
| | AVG. TRIP LENGTH | 0.27 | 0.28 | 0.55 | 0.20 | 0.35 | 0.55 | 0.27 | 0.35 | 0.62 | - | - | - | 0.26 | 0.32 | 0.58 |
| | NO. OF TRIPS | 3 | 4 | - | 1 | 4 | - | 6 | 2 | - | - | - | - | 10 | 10 | 20 |
| 700-1800 | AVG. RUN. TIME | 95 | 112 | 207 | 132 | 158 | 290 | 188 | 140 | 328 | 148 | 173 | 321 | 132 | 144 | 276 |
| | AVG. TRIP LENGTH | 0.25 | 0.30 | 0.55 | 0.43 | 0.42 | 0.85 | 0.50 | 0.55 | 1.05 | 0.45 | 0.70 | 1.15 | 0.38 | 0.44 | 0.83 |
| | NO. OF TRIPS | 4 | 4 | - | 4 | 6 | - | 2 | 2 | - | 2 | 2 | - | 12 | 14 | 26 |
| 800-1900 | AVG. RUN. TIME | 186 | 83 | 269 | 164 | 126 | 290 | 95 | 85 | 183 | - | - | - | 129 | 100 | 229 |
| | AVG. TRIP LENGTH | 0.40 | 0.13 | 0.53 | 0.38 | 0.32 | 0.70 | 0.26 | 0.30 | 0.56 | - | - | - | 0.31 | 0.22 | 0.53 |
| | NO. OF TRIPS | 2 | 7 | - | 4 | 5 | - | 8 | 1 | - | - | - | - | 14 | 13 | 27 |
| 900-2000 | AVG. RUN. TIME | 134 | 104 | 238 | 180 | 50 | 230 | 96 | 390 | 486 | - | 64 | - | 122 | 114 | 236 |
| | AVG. TRIP LENGTH | 0.40 | 0.28 | 0.68 | 0.20 | 0.20 | 0.40 | 0.38 | 0.90 | 12.8 | - | 0.20 | - | 0.37 | 0.31 | 0.68 |
| | NO. OF TRIPS | 4 | 5 | - | 1 | 2 | - | 4 | 1 | - | - | 2 | - | 9 | 10 | 19 |
| 2000-2100 | AVG. RUN. TIME | 350 | 180 | 530 | 159 | 184 | 343 | - | 210 | - | 121 | 133 | 254 | 197 | 174 | 371 |
| | AVG. TRIP LENGTH | 0.27 | 0.35 | 0.62 | 0.43 | 0.28 | 0.71 | - | 0.40 | - | 0.47 | 0.52 | 1.00 | 0.40 | 0.38 | 0.78 |
| | NO. OF TRIPS | 3 | 2 | - | 6 | 4 | - | - | 2 | - | 3 | 3 | - | 12 | 11 | 23 |
| 2100-2200 | AVG. RUN. TIME | 135 | 128 | 263 | 90 | 105 | 195 | 108 | 91 | 199 | 282 | 52 | 334 | 128 | 105 | 233 |
| | AVG. TRIP LENGTH | 0.48 | 0.30 | 0.78 | 0.25 | 0.23 | 0.48 | 0.40 | 0.30 | 0.70 | 1.10 | 0.15 | 1.25 | 0.46 | 0.25 | 0.71 |
| | NO. OF TRIPS | 4 | 5 | - | 2 | 3 | - | 5 | 1 | - | 1 | 2 | - | 12 | 11 | 23 |

FORM T/UP-4

Table B-1 (Cont). SUMMARY OF HOURLY AVERAGE RUNNING TIME AND TRIP LENGTH BY HOUR OF DAY AND GATE FOR EACH DAY OF THE STUDY PERIOD

COMPILED BY ________

CHECKED BY ________

**COMPLEX SOURCE TRAFFIC STUDY**

**LIBERTY TREE MALL, DANVERS, MASSACHUSETTS**

**DECEMBER 10 - 24, 1973**

DATE 12/18/73

DAY OF WEEK Tuesday

**RUNNING TIME STUDY — SUMMARY SHEET II**

| TIME OF DAY | AVG RUNNING TIME(SEC)<br>AVG TRIP LENGTH(MILES)<br>NO. OF TRIPS | GATE A | | | GATE B | | | GATE C | | | GATE D | | | ALL GATES | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | ARR | DEP | TOT | ARR | DEP | TOT | ARR | DEP | TOT | ARR | DEP | TOT | ARR | DEP | TOT |
| 1000-1100 | AVG. RUN. TIME | 97 | 83 | 180 | 168 | 113 | 281 | 119 | 75 | 194 | 89 | 168 | 257 | 116 | 101 | 216 |
| | AVG. TRIP LENGTH | 0.26 | 0.18 | 0.44 | 0.30 | 0.30 | 0.60 | 0.60 | 0.20 | 0.80 | 0.40 | 0.80 | 1.20 | 0.30 | 0.28 | 0.58 |
| | NO. OF TRIPS | 10 | 5 | - | 4 | 6 | - | 1 | 2 | - | 1 | 1 | - | 16 | 14 | 30 |
| 1100-1200 | AVG. RUN. TIME | 130 | 102 | 232 | 154 | 118 | 272 | 108 | 107 | 215 | 285 | 82 | 367 | 143 | 110 | 253 |
| | AVG. TRIP LENGTH | 0.38 | 0.23 | 0.61 | 0.40 | 0.36 | 0.76 | 0.50 | 0.37 | 0.87 | 0.60 | 0.40 | 100 | 0.42 | 0.34 | 0.76 |
| | NO. OF TRIPS | 8 | 3 | - | 3 | 8 | - | 2 | 3 | - | 1 | 1 | - | 14 | 15 | 29 |
| 1200-1300 | AVG. RUN. TIME | 149 | 131 | 280 | 209 | 157 | 366 | 130 | 230 | 350 | 247 | 122 | 369 | 177 | 143 | 320 |
| | AVG. TRIP LENGTH | 0.38 | 0.30 | 0.68 | 0.43 | 0.40 | 0.83 | 0.50 | 0.40 | 0.90 | 0.75 | 0.65 | 1.40 | 0.47 | 0.38 | 0.86 |
| | NO. OF TRIPS | 5 | 7 | - | 3 | 3 | - | 2 | 1 | - | 2 | 2 | - | 12 | 13 | 25 |
| 1300-1400 | AVG. RUN. TIME | 91 | 140 | 231 | 97 | 84 | 181 | 136 | 35 | 171 | 133 | 111 | 244 | 99 | 110 | 209 |
| | AVG. TRIP LENGTH | 0.29 | 0.20 | 0.49 | 0.30 | 0.14 | 0.44 | 0.40 | 0.10 | 0.50 | 0.50 | 0.40 | 0.90 | 0.31 | 0.19 | 0.50 |
| | NO. OF TRIPS | 7 | 7 | - | 7 | 5 | - | 1 | 1 | - | 1 | 1 | - | 16 | 14 | 30 |
| 1400-1500 | AVG. RUN. TIME | 90 | 137 | 227 | 146 | 65 | 211 | 110 | 124 | 234 | 118 | 84 | 202 | 124 | 95 | 220 |
| | AVG. TRIP LENGTH | 0.23 | 0.20 | 0.43 | 0.27 | 0.22 | 0.49 | 0.45 | 0.40 | 0.85 | 0.43 | 0.30 | 0.73 | 0.32 | 0.26 | 0.58 |
| | NO. OF TRIPS | 3 | 4 | - | 7 | 6 | - | 2 | 2 | - | 3 | 4 | - | 15 | 16 | 31 |
| 1500-1600 | AVG. RUN. TIME | 167 | 146 | 313 | 141 | 127 | 268 | - | - | - | - | - | - | 155 | 137 | 293 |
| | AVG. TRIP LENGTH | 0.33 | 0.30 | 0.63 | 0.36 | 0.26 | 0.62 | - | - | - | - | - | - | 0.34 | 0.28 | 0.62 |
| | NO. OF TRIPS | 6 | 6 | - | 5 | 5 | - | - | - | - | - | - | - | 11 | 11 | 22 |
| 1600-1700 | AVG. RUN. TIME | 86 | 84 | 170 | 284 | 109 | 393 | 66 | 91 | 157 | 112 | 110 | 222 | 136 | 98 | 234 |
| | AVG. TRIP LENGTH | 0.25 | 0.20 | 0.45 | 0.85 | 0.36 | 1.21 | 0.20 | 0.20 | 0.40 | 0.25 | 0.58 | 0.83 | 0.39 | 0.34 | 0.73 |
| | NO. OF TRIPS | 8 | 7 | - | 4 | 5 | - | 2 | 1 | - | 2 | 4 | - | 16 | 17 | 33 |
| 1700-1800 | AVG. RUN. TIME | 88 | 89 | 177 | 102 | 137 | 239 | 125 | 125 | 250 | 97 | 106 | 203 | 99 | 104 | 203 |
| | AVG. TRIP LENGTH | 0.27 | 0.30 | 0.57 | 0.40 | 0.40 | 0.80 | 0.47 | 0.47 | 0.94 | 0.35 | 0.47 | 0.82 | 0.34 | 0.40 | 0.74 |
| | NO. OF TRIPS | 7 | 7 | - | 1 | 1 | - | 3 | 3 | - | 6 | 6 | - | 17 | 17 | 34 |
| 1800-1900 | AVG. RUN. TIME | 210 | 139 | 349 | - | - | - | 51 | 167 | 218 | 138 | 85 | 223 | 163 | 119 | 282 |
| | AVG. TRIP LENGTH | 0.57 | 0.39 | 0.96 | - | - | - | 0.20 | 0.50 | 0.70 | 0.43 | 0.47 | 0.90 | 0.47 | 0.43 | 0.90 |
| | NO. OF TRIPS | 6 | 8 | - | - | - | - | 1 | 1 | - | 7 | 6 | - | 14 | 15 | 29 |
| 1900-2000 | AVG. RUN. TIME | 193 | 130 | 323 | 213 | 102 | 315 | - | 57 | - | - | - | - | 202 | 111 | 313 |
| | AVG. TRIP LENGTH | 0.37 | 0.22 | 0.59 | 0.44 | 0.14 | 0.58 | - | 0.20 | - | - | - | - | 0.40 | 0.18 | 0.58 |
| | NO. OF TRIPS | 6 | 5 | - | 5 | 5 | - | - | 1 | - | - | - | - | 11 | 11 | 22 |
| 2000-2100 | AVG. RUN. TIME | 172 | 313 | 485 | - | 130 | - | 107 | 252 | 359 | 230 | 76 | 306 | 150 | 200 | 350 |
| | AVG. TRIP LENGTH | 0.35 | 0.40 | 0.75 | - | 0.50 | - | 0.38 | 0.55 | 0.93 | 0.60 | 0.33 | 0.93 | 0.39 | 0.42 | 0.81 |
| | NO. OF TRIPS | 4 | 3 | - | - | 1 | - | 4 | 2 | - | 1 | 3 | - | 9 | 9 | 18 |
| 2100-2200 | AVG. RUN. TIME | 127 | 173 | 300 | 105 | 170 | 275 | 134 | 113 | 247 | 161 | 108 | 269 | 130 | 152 | 282 |
| | AVG. TRIP LENGTH | 0.34 | 0.29 | 0.63 | 0.55 | 0.25 | 0.80 | 0.45 | 0.45 | 0.90 | 0.75 | 0.47 | 1.22 | 0.45 | 0.34 | 0.79 |
| | NO. OF TRIPS | 7 | 8 | - | 2 | 2 | - | 2 | 2 | - | 2 | 3 | - | 13 | 15 | 28 |

FORM T/UP-4

Table B-1 (Cont.). SUMMARY OF HOURLY AVERAGE RUNNING TIME AND TRIP LENGTH BY HOUR OF DAY AND GATE FOR EACH DAY OF THE STUDY PERIOD

COMPILED BY ________

CHECKED BY ________

## COMPLEX SOURCE TRAFFIC STUDY
## LIBERTY TREE MALL, DANVERS, MASSACHUSETTS
## DECEMBER 10 - 24, 1973

DATE 12/19/73

DAY OF WEEK Wednesday

### RUNNING TIME STUDY — SUMMARY SHEET II

| TIME OF DAY | AVG RUNNING TIME(sec) AVG TRIP LENGTH(mi) NO. OF TRIPS | GATE A | | | GATE B | | | GATE C | | | GATE D | | | ALL GATES | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | ARR | DEP | TOT | ARR | DEP | TOT | ARR | DEP | TOT | ARR | DEP | TOT | ARR | DEP | TOT |
| 1000-1100 | AVG. RUN. TIME | 121 | 113 | 234 | 117 | 99 | 216 | 130 | 117 | 247 | 128 | 70 | 198 | 122 | 104 | 226 |
| | AVG. TRIP LENGTH | 0.34 | 0.34 | 0.68 | 0.33 | 0.30 | 0.63 | 0.50 | 0.40 | 0.90 | 0.47 | 0.35 | 0.82 | 0.38 | 0.34 | 0.72 |
| | NO. OF TRIPS | 7 | 7 | - | 3 | 2 | - | 1 | 1 | - | 3 | 2 | - | 14 | 12 | 26 |
| 1100-1200 | AVG. RUN. TIME | 78 | 94 | 172 | 115 | 85 | 200 | 78 | 90 | 168 | 127 | 92 | 219 | 87 | 91 | 178 |
| | AVG. TRIP LENGTH | 0.24 | 0.18 | 0.42 | 0.30 | 0.24 | 0.54 | 0.25 | 0.25 | 0.50 | 0.35 | 0.40 | 0.75 | 0.27 | 0.26 | 0.53 |
| | NO. OF TRIPS | 7 | 6 | - | 4 | 5 | - | 4 | 2 | - | 2 | 4 | - | 17 | 17 | 34 |
| 1200-1300 | AVG. RUN. TIME | 189 | 135 | 324 | 192 | 106 | 298 | 124 | 120 | 244 | 79 | 100 | 179 | 117 | 101 | 218 |
| | AVG. TRIP LENGTH | 0.40 | 0.50 | 0.90 | 0.60 | 0.10 | 0.70 | 0.35 | 0.55 | 0.90 | 0.28 | 0.34 | 0.62 | 0.34 | 0.38 | 0.72 |
| | NO. OF TRIPS | 3 | 2 | - | 1 | 1 | - | 2 | 2 | - | 8 | 8 | - | 14 | 13 | 27 |
| 1300-1400 | AVG. RUN. TIME | 144 | 116 | 260 | 139 | 125 | 264 | 78 | 159 | 237 | 90 | 102 | 192 | 134 | 119 | 253 |
| | AVG. TRIP LENGTH | 0.36 | 0.28 | 0.64 | 0.48 | 0.35 | 0.83 | 0.30 | 0.40 | 0.70 | 0.30 | 0.50 | 0.80 | 0.39 | 0.33 | 0.72 |
| | NO. OF TRIPS | 8 | 9 | - | 4 | 4 | - | 1 | 1 | - | 1 | 2 | - | 14 | 16 | 30 |
| 1400-1500 | AVG. RUN. TIME | 116 | 153 | 269 | 134 | 162 | 296 | 76 | 137 | 213 | 74 | 34 | 108 | 95 | 111 | 206 |
| | AVG. TRIP LENGTH | 0.35 | 0.38 | 0.73 | 0.55 | 0.45 | 1.00 | 0.25 | 0.40 | 0.65 | 0.27 | 0.12 | 0.39 | 0.33 | 0.31 | 0.64 |
| | NO. OF TRIPS | 4 | 5 | - | 2 | 2 | - | 2 | 3 | - | 6 | 5 | - | 14 | 15 | 29 |
| 1500-1600 | AVG. RUN. TIME | 92 | 97 | 189 | 70 | 76 | 146 | 110 | 140 | 250 | 160 | 109 | 269 | 113 | 111 | 224 |
| | AVG. TRIP LENGTH | 0.36 | 0.21 | 0.57 | 0.30 | 0.20 | 0.50 | 0.37 | 0.52 | 0.87 | 0.58 | 0.42 | 1.00 | 0.41 | 0.36 | 0.77 |
| | NO. OF TRIPS | 7 | 7 | - | 1 | 1 | - | 6 | 5 | - | 4 | 5 | - | 18 | 18 | 36 |
| 1600-1700 | AVG. RUN. TIME | 97 | 146 | 243 | 110 | 126 | 236 | - | - | - | - | - | - | 102 | 142 | 244 |
| | AVG. TRIP LENGTH | 0.29 | 0.33 | 0.62 | 0.40 | 0.30 | 0.70 | - | - | - | - | - | - | 0.33 | [illegible] | 0.65 |
| | NO. OF TRIPS | 7 | 7 | - | 4 | 2 | - | - | - | - | - | - | - | 11 | 9 | 20 |
| 1700-1800 | AVG. RUN. TIME | 105 | 113 | 218 | 96 | 74 | 170 | 95 | 113 | 208 | 58 | 81 | 139 | 98 | 99 | 197 |
| | AVG. TRIP LENGTH | 0.41 | 0.26 | 0.67 | 0.20 | 0.33 | 0.53 | 0.35 | 0.30 | 0.65 | 0.20 | 0.40 | 0.60 | 0.34 | 0.31 | 0.65 |
| | NO. OF TRIPS | 8 | 7 | - | 3 | 3 | - | 2 | 2 | - | 1 | 3 | - | 14 | 15 | 29 |
| 1800-1900 | AVG. RUN. TIME | 105 | 125 | 230 | 108 | 93 | 201 | 94 | 95 | 189 | 130 | 119 | 249 | 114 | 99 | 213 |
| | AVG. TRIP LENGTH | 0.30 | 0.50 | 0.80 | 0.30 | 0.40 | 0.70 | 0.32 | 0.32 | 0.64 | 0.53 | 0.46 | 0.99 | 0.42 | 0.41 | 0.83 |
| | NO. OF TRIPS | 1 | 1 | - | 2 | 1 | - | 5 | 6 | - | 8 | 8 | - | 16 | 16 | 32 |
| 1900-2000 | AVG. RUN. TIME | 135 | 192 | 327 | 278 | 145 | 423 | 104 | 284 | 388 | 188 | 113 | 301 | 166 | 168 | 334 |
| | AVG. TRIP LENGTH | 0.30 | 0.27 | 0.57 | 0.50 | 0.30 | 0.80 | 0.35 | 0.55 | 0.90 | 0.52 | 0.52 | 1.04 | 0.43 | 0.44 | 0.87 |
| | NO. OF TRIPS | 3 | 3 | - | 1 | 1 | - | 2 | 2 | - | 5 | 5 | - | 11 | 11 | 22 |
| 2000-2100 | AVG. RUN. TIME | 86 | 240 | 326 | - | - | - | 355 | 392 | 747 | 94 | 82 | 176 | 180 | 160 | 340 |
| | AVG. TRIP LENGTH | 0.20 | 0.20 | 0.40 | - | - | - | 0.67 | 0.60 | 1.27 | 0.15 | 0.16 | 0.31 | 0.33 | 0.25 | 0.58 |
| | NO. OF TRIPS | 2 | 1 | - | - | - | - | 3 | 2 | - | 4 | 7 | - | 9 | 10 | 19 |
| 2100-2200 | AVG. RUN. TIME | 83 | 85 | 168 | 130 | 162 | 292 | 140 | 200 | 340 | 76 | 66 | 142 | 96 | 111 | 207 |
| | AVG. TRIP LENGTH | 0.20 | 0.20 | 0.40 | 0.50 | 0.48 | 0.98 | 0.45 | 0.60 | 1.05 | 0.29 | 0.25 | 0.54 | 0.35 | 0.35 | 0.70 |
| | NO. OF TRIPS | 1 | 1 | - | 3 | 4 | - | 2 | 2 | - | 9 | 8 | - | 15 | 15 | 30 |

FORM T/UP-4

Table B-1 (Cont). SUMMARY OF HOURLY AVERAGE RUNNING TIME AND TRIP LENGTH BY HOUR OF DAY AND GATE FOR EACH DAY OF THE STUDY PERIOD

COMPILED BY ______

CHECKED BY ______

## COMPLEX SOURCE TRAFFIC STUDY
## LIBERTY TREE MALL, DANVERS, MASSACHUSETTS
## DECEMBER 10 - 24, 1973

DATE 12/20/73

DAY OF WEEK Thursday

### RUNNING TIME STUDY — SUMMARY SHEET II

| TIME OF DAY | AVG RUNNING TIME (sec) AVG TRIP LENGTH (miles) NO. OF TRIPS | GATE A | | | GATE B | | | GATE C | | | GATE D | | | ALL GATES | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | ARR | DEP | TOT | ARR | DEP | TOT | ARR | DEP | TOT | ARR | DEP | TOT | ARR | DEP | TOT |
| 1000-1100 | AVG. RUN. TIME | 138 | 140 | 278 | 120 | 84 | 204 | 154 | 169 | 323 | 56 | 60 | 116 | 126 | 115 | 241 |
| | AVG. TRIP LENGTH | 0.30 | 0.37 | 0.67 | 0.38 | 0.28 | 0.66 | 0.34 | 0.43 | 0.77 | 0.20 | 0.25 | 0.45 | 0.32 | 0.33 | 0.66 |
| | NO. OF TRIPS | 2 | 3 | - | 4 | 4 | - | 5 | 3 | - | 2 | 2 | - | 13 | 12 | 25 |
| 1100-1200 | AVG. RUN. TIME | 97 | 115 | 212 | 148 | 77 | 225 | 117 | 27 | 144 | 37 | 23 | 60 | 114 | 82 | 196 |
| | AVG. TRIP LENGTH | 0.23 | 0.30 | 0.53 | 0.43 | 0.43 | 0.86 | 0.30 | 0.10 | 0.46 | 0.10 | 0.10 | 0.20 | 0.30 | 0.31 | 0.61 |
| | NO. OF TRIPS | 4 | 4 | - | 4 | 4 | - | 2 | 1 | - | 1 | 1 | - | 11 | 10 | 21 |
| 1200-1300 | AVG. RUN. TIME | 117 | 117 | 234 | 142 | 145 | 287 | - | - | - | 90 | 138 | 228 | 115 | 136 | 251 |
| | AVG. TRIP LENGTH | 0.37 | 0.37 | 0.74 | 0.40 | 0.60 | 1.00 | - | - | - | 0.40 | 0.50 | 0.90 | 0.38 | 0.37 | 0.75 |
| | NO. OF TRIPS | 11 | 11 | - | 1 | 1 | - | - | - | - | 2 | 2 | - | 14 | 13 | 27 |
| 1300-1400 | AVG. RUN. TIME | 130 | 131 | 261 | 100 | 80 | 180 | 103 | 138 | 241 | 110 | 74 | 184 | 113 | 111 | 224 |
| | AVG. TRIP LENGTH | 0.47 | 0.28 | 0.75 | 0.38 | 0.35 | 0.73 | 0.40 | 0.43 | 0.83 | 0.40 | 0.25 | 0.65 | 0.42 | 0.33 | 0.75 |
| | NO. OF TRIPS | 6 | 6 | - | 5 | 4 | - | 3 | 3 | - | 1 | 2 | - | 15 | 15 | 30 |
| 1400-1500 | AVG. RUN. TIME | 126 | 139 | 265 | 74 | 94 | 168 | - | - | - | 88 | 103 | 191 | 91 | 110 | 201 |
| | AVG. TRIP LENGTH | 0.45 | 0.23 | 0.68 | 0.33 | 0.30 | 0.63 | - | - | - | 0.40 | 0.30 | 0.70 | 0.37 | 0.28 | 0.65 |
| | NO. OF TRIPS | 4 | 4 | - | 8 | 6 | - | - | - | - | 2 | 3 | - | 14 | 13 | 27 |
| 1500-1600 | AVG. RUN. TIME | 107 | 132 | 139 | 122 | 103 | 225 | 92 | 178 | 270 | 118 | 160 | 278 | 108 | 136 | 244 |
| | AVG. TRIP LENGTH | 0.30 | 0.39 | 0.69 | 0.50 | 0.87 | 1.37 | 0.30 | 0.65 | 0.95 | 0.55 | 0.70 | 1.25 | 0.36 | 0.44 | 0.80 |
| | NO. OF TRIPS | 9 | 7 | - | 3 | 3 | - | 4 | 2 | - | 2 | 2 | - | 18 | 14 | 32 |
| 1600-1700 | AVG. RUN. TIME | 78 | 77 | 1155 | 115 | 130 | 245 | 44 | 57 | 101 | 106 | 96 | 202 | 94 | 96 | 190 |
| | AVG. TRIP LENGTH | 0.28 | 0.22 | 0.50 | 0.53 | 0.40 | 0.93 | 0.20 | 0.20 | 0.40 | 0.42 | 0.32 | 0.74 | 0.38 | 0.29 | 0.67 |
| | NO. OF TRIPS | 6 | 5 | - | 4 | 4 | - | 1 | 1 | - | 5 | 5 | - | 16 | 15 | 31 |
| 1700-1800 | AVG. RUN TIME | 95 | 155 | 250 | 107 | 56 | 163 | 95 | 144 | 239 | 77 | 125 | 202 | 97 | 110 | 207 |
| | AVG. TRIP LENGTH | 0.30 | 0.45 | 0.75 | 0.35 | 0.30 | 0.65 | 0.37 | 0.58 | 0.95 | 0.33 | 0.40 | 0.74 | 0.34 | 0.42 | 0.76 |
| | NO. OF TRIPS | 2 | 2 | - | 6 | 5 | - | 3 | 4 | - | 3 | 3 | - | 14 | 14 | 28 |
| 1800-1900 | AVG. RUN TIME | 151 | 124 | 275 | 151 | 126 | 277 | 136 | 163 | 299 | - | - | - | 148 | 138 | 286 |
| | AVG. TRIP LENGTH | 0.40 | 0.20 | 0.60 | 0.48 | 0.36 | 0.84 | 0.47 | 0.50 | 0.97 | - | - | - | 0.45 | 0.33 | 0.78 |
| | NO. OF TRIPS | 4 | 4 | - | 6 | 7 | - | 3 | 2 | - | - | - | - | 13 | 13 | 26 |
| 1900-2000 | AVG. RUN. TIME | 170 | 203 | 373 | 178 | 95 | 273 | 229 | 158 | 387 | 137 | - | - | 182 | 151 | 333 |
| | AVG. TRIP LENGTH | 0.27 | 0.37 | 0.64 | 0.40 | 0.27 | 0.67 | 0.35 | 0.35 | 0.70 | 0.40 | - | - | 0.34 | 0.33 | 0.67 |
| | NO. OF TRIPS | 3 | 3 | - | 3 | 3 | - | 2 | 2 | - | 1 | - | - | 9 | 8 | 17 |
| 2000-2100 | AVG. RUN TIME | 135 | 155 | 290 | 164 | 178 | 342 | 120 | 194 | 314 | 262 | 111 | 373 | 180 | 158 | 338 |
| | AVG. TRIP LENGTH | 0.25 | 0.40 | 0.65 | 0.30 | 0.75 | 1.05 | 0.40 | 0.43 | 0.83 | 0.60 | 0.50 | 1.10 | 0.41 | 0.42 | 0.83 |
| | NO. OF TRIPS | 2 | 1 | - | 2 | 2 | - | 2 | 3 | - | 3 | 3 | - | 9 | 9 | 18 |
| 2100-2200 | AVG. RUN TIME | 160 | 124 | 284 | 84 | 146 | 230 | 92 | 165 | 257 | 120 | 115 | 235 | 115 | 128 | 243 |
| | AVG. TRIP LENGTH | 0.40 | 0.20 | 0.60 | 0.27 | 0.37 | 0.64 | 0.30 | 0.60 | 0.90 | 0.46 | 0.50 | 0.96 | 0.38 | 0.45 | 0.83 |
| | NO. OF TRIPS | 2 | 1 | - | 3 | 3 | - | 1 | 1 | - | 5 | 7 | - | 11 | 12 | 23 |

FORM T/UP-4

Tab B-1 (C SUMMARY OF HOURLY AVERAGE RUNNING TIME AND TRIP LENGTH BY HOUR OF DAY AND GATE FOR EACH DAY OF THE STUDY PERIOD

COMPILED BY ______

CHECKED BY ______

**COMPLEX SOURCE TRAFFIC STUDY**
**LIBERTY TREE MALL, DANVERS, MASSACHUSETTS**
**DECEMBER 10 - 24, 1973**

DATE 12-21-73

DAY OF WEEK Friday

**RUNNING TIME STUDY — SUMMARY SHEET II**

| TIME OF DAY | AVG RUNNING TIME(sec) AVG TRIP LENGTH(miles) NO. OF TRIPS | GATE A |  |  | GATE B |  |  | GATE C |  |  | GATE D |  |  | ALL GATES |  |  |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
|  |  | ARR | DEP | TOT | ARR | DEP | TOT | ARR | DEP | TOT | ARR | DEP | TOT | ARR | DEP | TOT |
| 1000-1100 | AVG. RUN. TIME | 83 | 134 | 217 | 145 | 114 | 259 | 126 | 152 | 278 | 99 | 92 | 191 | 105 | 115 | 220 |
|  | AVG. TRIP LENGTH | 0.22 | 0.33 | 0.55 | 0.53 | 0.28 | 0.81 | 0.30 | 0.30 | 0.66 | 0.44 | 0.38 | 0.82 | 0.37 | 0.32 | 0.69 |
|  | NO. OF TRIPS | 5 | 3 | - | 3 | 5 | - | 1 | 1 | - | 5 | 4 | - | 14 | 13 | 27 |
| 1100-1200 | AVG. RUN. TIME | 122 | 95 | 217 | 98 | 91 | 189 | 83 | 118 | 201 | 0 | 0 | - | 111 | 99 | 200 |
|  | AVG. TRIP LENGTH | 0.33 | 0.30 | 0.63 | 0.38 | 0.33 | 0.71 | 0.35 | 0.33 | 0.68 | 0 | 0 | - | 0.34 | 0.31 | 0.65 |
|  | NO. OF TRIPS | 11 | 10 | - | 5 | 3 | - | 2 | 3 | - | 0 | 0 | - | 18 | 16 | 34 |
| 1200-1300 | AVG. RUN. TIME | 127 | 111 | 238 | 116 | 170 | 286 | 135 | 0 | - | 188 | 127 | 315 | 137 | 131 | 268 |
|  | AVG. TRIP LENGTH | 0.42 | 0.34 | 0.76 | 0.33 | 0.40 | 0.73 | 0.40 | 0 | - | 0.77 | 0.38 | 1.15 | 0.46 | 0.37 | 0.83 |
|  | NO. OF TRIPS | 5 | 5 | - | 4 | 3 | - | 2 | 0 | - | 3 | 4 | - | 14 | 12 | 26 |
| 1300-1400 | AVG. RUN. TIME | 168 | 149 | 317 | 70 | 154 | 224 | 96 | 85 | 181 | 106 | 75 | 181 | 149 | 139 | 288 |
|  | AVG. TRIP LENGTH | 0.46 | 0.33 | 0.79 | 0.15 | 0.40 | 0.55 | 0.30 | 0.30 | 0.60 | 0.40 | 0.40 | 0.80 | 0.39 | 0.34 | 0.73 |
|  | NO. OF TRIPS | 8 | 10 | - | 2 | 2 | - | 1 | 1 | - | 1 | 1 | - | 12 | 14 | 26 |
| 1400-1500 | AVG. RUN. TIME | 140 | 205 | 345 | 125 | 114 | 239 | 116 | 102 | 218 | 105 | 84 | 189 | 127 | 129 | 256 |
|  | AVG. TRIP LENGTH | 0.40 | 0.33 | 0.73 | 0.47 | 0.30 | 0.77 | 0.44 | 0.47 | 0.91 | 0.30 | 0.30 | 0.60 | 0.42 | 0.35 | 0.77 |
|  | NO. OF TRIPS | 6 | 3 | - | 3 | 4 | - | 5 | 3 | - | 1 | 2 |  | 15 | 12 | 27 |
| 1500-1600 | AVG. RUN. TIME | 100 | 107 | 207 | 132 | 121 | 253 | 110 | 185 | 295 | 98 | 69 | 167 | 110 | 112 | 222 |
|  | AVG. TRIP LENGTH | 0.38 | 0.28 | 0.66 | 0.40 | 0.40 | 0.80 | 0.30 | 0.40 | 0.70 | 0.40 | 0.35 | 0.75 | 0.39 | 0.34 | 0.73 |
|  | NO. OF TRIPS | 6 | 5 | - | 4 | 4 | - | 1 | 1 | - | 2 | 2 | - | 13 | 12 | 25 |
| 1600-1700 | AVG. RUN. TIME | 117 | 114 | 231 | 256 | 103 | 348 | 155 | 149 | 204 | 165 | 124 | 289 | 147 | 117 | 264 |
|  | AVG. TRIP LENGTH | 0.30 | 0.28 | 0.58 | 0.75 | 0.33 | 1.08 | 0.53 | 0.50 | 0.93 | 0.70 | 0.40 | 1.10 | 0.47 | 0.34 | 0.81 |
|  | NO. OF TRIPS | 9 | 6 | - | 2 | 4 | - | 3 | 1 | - | 3 | 5 | - | 17 | 16 | 33 |
| 1700-1800 | AVG. RUN. TIME | 97 | 92 | 189 | 111 | 77 | 188 | 0 | 0 | - | 146 | 105 | 251 | 111 | 91 | 202 |
|  | AVG. TRIP LENGTH | 0.30 | 0.23 | 0.53 | 0.35 | 0.45 | 0.80 | 0 | 0 | - | 0.60 | 0.60 | 1.20 | 0.38 | 0.32 | 0.70 |
|  | NO. OF TRIPS | 8 | 9 | - | 2 | 2 | - | 0 | 0 | - | 3 | 2 | - | 13 | 13 | 26 |
| 1800-1900 | AVG. RUN. TIME | 115 | 93 | 208 | 159 | 89 | 248 | 0 | 0 | - | 141 | 117 | 258 | 130 | 96 | 226 |
|  | AVG. TRIP LENGTH | 0.38 | 0.23 | 0.61 | 0.40 | 0.45 | 0.85 | 0 | 0 | - | 0.63 | 0.63 | 1.26 | 0.46 | 0.43 | 0.89 |
|  | NO. OF TRIPS | 6 | 4 | - | 2 | 4 | - | 0 | 0 | - | 3 | 4 | - | 11 | 12 | 23 |
| 1900-2000 | AVG. RUN. TIME | 175 | 127 | 302 | 241 | 174 | 415 | 0 | 0 | - | 158 | 97 | 255 | 180 | 142 | 322 |
|  | AVG. TRIP LENGTH | 0.39 | 0.32 | 0.71 | 0.55 | 0.35 | 0.90 | 0 | 0 | - | 0.60 | 0.43 | 1.03 | 0.47 | 0.35 | 0.82 |
|  | NO. OF TRIPS | 8 | 6 | - | 2 | 4 | - | 0 | 0 | - | 4 | 3 | - | 14 | 13 | 27 |
| 2000-2100 | AVG. RUN. TIME | 131 | 72 | 203 | 143 | 85 | 228 | 0 | 0 | - | 233 | 83 | 316 | 142 | 81 | 223 |
|  | AVG. TRIP LENGTH | 0.26 | 0.20 | 0.46 | 0.33 | 0.15 | 0.48 | 0 | 0 | - | 0.80 | 0.30 | 1.10 | 0.32 | 0.20 | 0.52 |
|  | NO. OF TRIPS | 9 | 1 | - | 7 | 2 | - | 0 | 0 | - | 1 | 1 | - | 17 | 4 | 21 |
| 2100-2200 | AVG. RUN. TIME | 121 | 244 | 365 | 179 | 0 | - | 160 | 92 | 252 | 79 | 72 | 151 | 120 | 143 | 263 |
|  | AVG. TRIP LENGTH | 0.35 | 0.33 | 0.68 | 0.40 | 0 | - | 0.60 | 0.30 | 0.90 | 0.30 | 0.42 | 0.72 | 0.36 | 0.37 | 0.73 |
|  | NO. OF TRIPS | 4 | 4 | - | 2 | 0 | - | 1 | 1 | - | 4 | 5 | - | 11 | 10 | 21 |

FORM T/UP-4

Table B-1 (Cont). SUMMARY OF HOURLY AVERAGE RUNNING TIME AND TRIP LENGTH BY HOUR OF DAY AND GATE FOR EACH DAY OF THE STUDY PERIOD

COMPILED BY ________

CHECKED BY ________

## COMPLEX SOURCE TRAFFIC STUDY
## LIBERTY TREE MALL, DANVERS, MASSACHUSETTS
## DECEMBER 10 - 24, 1973

DATE 12/22/73

DAY OF WEEK Saturday

### RUNNING TIME STUDY — SUMMARY SHEET II

| TIME OF DAY | AVG RUNNING TIME AVG TRIP LENGTH NO. OF TRIPS | GATE A | | | GATE B | | | GATE C | | | GATE D | | | ALL GATES | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | ARR | DEP | TOT | ARR | DEP | TOT | ARR | DEP | TOT | ARR | DEP | TOT | ARR | DEP | TOT |
| 1000-1100 | AVG. RUN. TIME | 128 | 121 | 249 | 153 | 125 | 278 | 119 | 145 | 264 | 162 | 122 | 284 | 142 | 125 | 267 |
| | AVG TRIP LENGTH | 0.47 | 0.50 | 0.97 | 0.40 | 0.34 | 0.74 | 0.60 | 0.70 | 1.30 | 0.50 | 0.40 | 0.90 | 0.47 | 0.43 | 0.90 |
| | NO OF TRIPS | 3 | 3 | - | 4 | 5 | - | 2 | 1 | - | 2 | 2 | - | 11 | 11 | 22 |
| 1100-1200 | AVG. RUN. TIME | 240 | 132 | 372 | 172 | 161 | 333 | 258 | 214 | 472 | 109 | 102 | 211 | 158 | 132 | 290 |
| | AVG. TRIP LENGTH | 0.60 | 0.50 | 1.10 | 0.53 | 0.60 | 1.13 | 0.37 | 0.73 | 1.50 | 0.49 | 0.47 | 0.96 | 0.55 | 0.53 | 1.08 |
| | NO. OF TRIPS | 1 | 3 | - | 4 | 1 | - | 3 | 3 | - | 9 | 9 | - | 17 | 15 | 33 |
| 1200-1300 | AVG. RUN. TIME | 368 | 446 | 814 | 0 | 60 | - | 219 | 917 | 1136 | 156 | 85 | 241 | 297 | 355 | 652 |
| | AVG. TRIP LENGTH | 0.66 | 0.53 | 1.19 | 0 | 0.20 | - | 0.60 | 1.70 | 2.30 | 0.65 | 0.45 | 1.10 | 0.65 | 0.63 | 1.28 |
| | NO. OF TRIPS | 5 | 3 | - | 0 | 1 | - | 1 | 1 | - | 2 | 2 | - | 8 | 7 | 15 |
| 1300-1400 | AVG. RUN. TIME | 197 | 155 | 352 | 89 | 134 | 223 | 0 | 149 | - | 41 | 45 | 86 | 138 | 145 | 243 |
| | AVG TRIP LENGTH | 0.38 | 0.20 | 0.58 | 0.35 | 0.43 | 0.78 | 0 | 0.65 | - | 0.30 | 0.50 | 0.80 | 0.36 | 0.41 | 0.77 |
| | NO OF TRIPS | 5 | 3 | - | 4 | 3 | - | 0 | 2 | - | 1 | 1 | - | 10 | 9 | 19 |
| 1400-1500 | AVG. RUN. TIME | 364 | 453 | 817 | 144 | 84 | 228 | 116 | 229 | 345 | 0 | 0 | - | 230 | 276 | 506 |
| | AVG. TRIP LENGTH | 0.33 | 0.33 | 0.66 | 0.60 | 0.20 | 0.80 | 0.30 | 0.47 | 0.77 | 0 | 0 | - | 0.40 | 0.35 | 0.75 |
| | NO. OF TRIPS | 3 | 3 | - | 2 | 2 | - | 2 | 3 | - | 0 | 0 | - | 7 | 8 | 15 |
| 1500-1600 | AVG. RUN. TIME | 149 | 259 | 408 | 0 | 67 | - | 114 | 148 | 262 | 98 | 124 | 222 | 117 | 168 | 285 |
| | AVG. TRIP LENGTH | 0.20 | 0.20 | 0.40 | 0 | 0.20 | - | 0.30 | 0.45 | 0.75 | 0.25 | 0.35 | 0.60 | 0.26 | 0.33 | 0.59 |
| | NO. OF TRIPS | 3 | 3 | - | 0 | 1 | - | 4 | 4 | - | 4 | 2 | - | 11 | 10 | 21 |
| 1600-1700 | AVG RUN. TIME | 207 | 0 | - | 83 | 182 | 265 | 130 | 190 | 320 | 133 | 164 | 297 | 127 | 178 | 305 |
| | AVG. TRIP LENGTH | 0.30 | 0 | - | 0.37 | 0.60 | 0.97 | 0.63 | 0.60 | 1.23 | 0.54 | 0.70 | 1.24 | 0.51 | 0.64 | 1.15 |
| | NO. OF TRIPS | 1 | 0 | - | 3 | 1 | - | 3 | 2 | - | 7 | 2 | - | 14 | 5 | 19 |
| 1700-1800 | AVG RUN TIME | 150 | 166 | 316 | 157 | 143 | 300 | 284 | 156 | 440 | 115 | 134 | 249 | 172 | 153 | 325 |
| | AVG. TRIP LENGTH | 0.33 | 0.27 | 0.60 | 0.50 | 0.40 | 0.90 | 0.60 | 0.60 | 1.20 | 0.40 | 0.48 | 0.88 | 0.41 | 0.39 | 0.80 |
| | NO. OF TRIPS | 6 | 7 | - | 1 | 1 | - | 2 | 2 | - | 3 | 4 | - | 12 | 14 | 26 |
| 1800-1900 | AVG. RUN. TIME | 110 | 109 | 219 | 160 | 120 | 280 | 66 | 72 | 138 | 125 | 99 | 224 | 126 | 102 | 228 |
| | AVG. TRIP LENGTH | 0.28 | 0.25 | 0.53 | 0.37 | 0.28 | 0.65 | 0.23 | 0.40 | 0.63 | 0.60 | 0.40 | 1.00 | 0.34 | 0.32 | 0.66 |
| | NO. OF TRIPS | 4 | 4 | - | 6 | 5 | - | 4 | 4 | - | 2 | 2 | - | 16 | 15 | 31 |
| 1900-2000 | AVG. RUN. TIME | 114 | 103 | 217 | 69 | 77 | 146 | 213 | 0 | - | 148 | 123 | 271 | 119 | 100 | 219 |
| | AVG. TRIP LENGTH | 0.35 | 0.28 | 0.63 | 0.20 | 0.25 | 0.45 | 0.60 | 0 | - | 0.70 | 0.80 | 1.50 | 0.39 | 0.32 | 0.71 |
| | NO. OF TRIPS | 10 | 10 | - | 2 | 2 | - | 1 | 0 | - | 2 | 1 | - | 15 | 13 | 28 |
| 2000-2100 | AVG. RUN. TIME | 225 | 168 | 393 | 90 | 0 | - | 125 | 146 | 271 | 113 | 206 | 319 | 178 | 180 | 358 |
| | AVG. TRIP LENGTH | 0.57 | 0.43 | 1.00 | 0.30 | 0 | - | 0.40 | 0.30 | 0.70 | 0.47 | 0.55 | 1.02 | 0.51 | 0.46 | 0.97 |
| | NO. OF TRIPS | 7 | 6 | - | 1 | 0 | - | 1 | 1 | - | 3 | 4 | - | 12 | 11 | 23 |
| 2100-2200 | AVG. RUN. TIME | 137 | 185 | 322 | 86 | 273 | 359 | 145 | 188 | 333 | 92 | 161 | 253 | 118 | 198 | 316 |
| | AVG. TRIP LENGTH | 0.43 | 0.35 | 0.78 | 0.30 | 0.50 | 0.80 | 0.40 | 0.80 | 1.20 | 0.30 | 0.50 | 0.80 | 0.37 | 0.50 | 0.87 |
| | NO. OF TRIPS | 3 | 2 | - | 1 | 1 | - | 1 | 1 | - | 2 | 1 | - | 7 | 5 | 12 |

FORM T/IP-4

Table B-1 (Cont) SUMMARY OF HOURLY AVERAGE RUNNING TIME AND TRIP LENGTH BY HOUR OF DAY AND GATE FOR EACH DAY OF THE STUDY PERIOD

COMPILED BY ________

CHECKED BY ________

**COMPLEX SOURCE TRAFFIC STUDY**
**LIBERTY TREE MALL, DANVERS, MASSACHUSETTS**
**DECEMBER 10 - 24, 1973**

DATE 12/24/73

DAY OF WEEK Monday

**RUNNING TIME STUDY — SUMMARY SHEET II**

| TIME OF DAY | AVG RUNNING TIME sec<br>AVG TRIP LENGTH mi<br>NO. OF TRIPS | GATE A | | | GATE B | | | GATE C | | | GATE D | | | ALL GATES | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | ARR | DEP | TOT | ARR | DEP | TOT | ARR | DEP | TOT | ARR | DEP | TOT | ARR | DEP | TOT |
| 1000-1100 | AVG. RUN. TIME | 91 | 161 | 252 | 140 | 143 | 283 | 130 | 419 | 549 | 58 | 92 | 150 | 103 | 210 | 313 |
| | AVG. TRIP LENGTH | 0.23 | 0.20 | 0.43 | 0.50 | 0.45 | 0.95 | 0.20 | 0.95 | 1.15 | 0.15 | 0.40 | 0.55 | 0.27 | 0.54 | 0.81 |
| | NO. OF TRIPS | 3 | 1 | - | 2 | 2 | - | 2 | 2 | - | 2 | 2 | - | 9 | 7 | 16 |
| 1100-1200 | AVG. RUN. TIME | 359 | 267 | 626 | 166 | 111 | 277 | 33 | 0 | - | 129 | 285 | 414 | 165 | 165 | 330 |
| | AVG. TRIP LENGTH | 0.60 | 0.70 | 1.30 | 0.36 | 0.45 | 0.81 | 0.10 | 0 | - | 0.40 | 0.80 | 1.20 | 0.36 | 0.54 | 0.90 |
| | NO. OF TRIPS | 1 | 3 | - | 7 | 8 | - | 1 | 0 | - | 2 | 1 | - | 11 | 12 | 23 |
| 1200-1300 | AVG. RUN. TIME | 167 | 149 | 316 | 146 | 162 | 308 | 0 | 0 | - | 95 | 108 | 203 | 142 | 142 | 284 |
| | AVG. TRIP LENGTH | 0.34 | 0.40 | 0.74 | 0.38 | 0.35 | 0.73 | 0 | 0 | - | 0.33 | 0.43 | 0.76 | 0.35 | 0.39 | 0.74 |
| | NO. OF TRIPS | 5 | 3 | - | 4 | 4 | - | 0 | 0 | - | 3 | 3 | - | 12 | 10 | 22 |
| 1300-1400 | AVG. RUN. TIME | 159 | 115 | 274 | 296 | 115 | 411 | 64 | 321 | 385 | 75 | 137 | 212 | 155 | 158 | 313 |
| | AVG. TRIP LENGTH | 0.15 | 0.25 | 0.40 | 0.43 | 0.33 | 0.76 | 0.20 | 0.45 | 0.65 | 0.35 | 0.50 | 0.85 | 0.29 | 0.38 | 0.67 |
| | NO. OF TRIPS | 2 | 2 | - | 3 | 4 | - | 3 | 2 | - | 2 | 3 | - | 10 | 11 | 21 |
| 1400-1500 | AVG. RUN. TIME | 340 | 220 | 560 | 231 | 181 | 412 | 162 | 262 | 424 | 183 | 133 | 316 | 201 | 208 | 409 |
| | AVG. TRIP LENGTH | 0.40 | 0.30 | 0.70 | 0.43 | 0.25 | 0.60 | 0.35 | 0.44 | 0.79 | 0.55 | 0.53 | 1.08 | 0.44 | 0.42 | 0.86 |
| | NO. OF TRIPS | 1 | 1 | - | 3 | 2 | - | 4 | 5 | - | 4 | 3 | - | 12 | 11 | 23 |
| 1500-1600 | AVG. RUN. TIME | 208 | 177 | 385 | 104 | 228 | 332 | 88 | 159 | 247 | 188 | 104 | 292 | 142 | 163 | 305 |
| | AVG. TRIP LENGTH | 0.27 | 0.40 | 0.67 | 0.25 | 0.55 | 0.80 | 0.38 | 0.40 | 0.78 | 0.95 | 0.47 | 1.42 | 0.43 | 0.44 | 0.87 |
| | NO. OF TRIPS | 3 | 4 | - | 2 | 2 | - | 4 | 3 | - | 2 | 3 | - | 11 | 12 | 23 |
| 1600-1700 | AVG. RUN. TIME | 88 | 117 | 205 | 67 | 130 | 197 | 86 | 93 | 179 | 64 | 97 | 161 | 83 | 107 | 190 |
| | AVG. TRIP LENGTH | 0.31 | 0.26 | 0.57 | 0.23 | 0.80 | 1.03 | 0.25 | 0.40 | 0.65 | 0.70 | 0.33 | 1.03 | 0.31 | 0.35 | 0.66 |
| | NO. OF TRIPS | 10 | 5 | - | 3 | 1 | - | 2 | 1 | - | 1 | 3 | - | 16 | 10 | 26 |
| 1700-1800 | AVG. RUN. TIME | 97 | 106 | 203 | 50 | 233 | 283 | 102 | 117 | 219 | 0 | 0 | - | 119 | 133 | 252 |
| | AVG. TRIP LENGTH | 0.34 | 0.25 | 0.59 | 0.30 | 0.35 | 0.65 | 0.35 | 0.55 | 0.90 | 0 | 0 | - | 0.34 | 0.33 | 0.67 |
| | NO. OF TRIPS | 7 | 6 | - | 1 | 2 | - | 2 | 2 | - | 0 | 0 | - | 10 | 10 | 20 |
| 1800-1900 | AVG. RUN. TIME | | | | | | | | | | | | | | | |
| | AVG. TRIP LENGTH | | | | | | | | | | | | | | | |
| | NO. OF TRIPS | | | | | | | | | | | | | | | |
| 1900-2000 | AVG. RUN. TIME | | | | | | | | | | | | | | | |
| | AVG. TRIP LENGTH | | | | | | | | | | | | | | | |
| | NO. OF TRIPS | | | | | | | | | | | | | | | |
| 2000-2100 | AVG. RUN. TIME | | | | | | | | | | | | | | | |
| | AVG. TRIP LENGTH | | | | | | | | | | | | | | | |
| | NO. OF TRIPS | | | | | | | | | | | | | | | |
| 2100-2200 | AVG. RUN. TIME | | | | | | | | | | | | | | | |
| | AVG. TRIP LENGTH | | | | | | | | | | | | | | | |
| | NO. OF TRIPS | | | | | | | | | | | | | | | |

FORM T/UP-4

# APPENDIX C

## TRAFFIC AND PARKING CHARACTERISTICS

Table C-1 presents hourly traffic and parking characteristics at the Liberty Tree Mall during the period of study. Included are traffic volumes, parking lot utilization (percent capacity), running times, and average speeds. The outbound traffic volumes given in this table for the calculation of lot utilization were obtained by proportionally increasing the values listed in Table A-1 to ensure a 100-vehicle excess 1 hour after the close of the principal stores within the shopping center. This arbitrary adjustment was made to compensate for a bias in the outbound traffic counts. Since traffic volumes are recorded for the end of each hour, the percent capacity for a given hour is calculated as the average of the excess vehicles at the beginning and end of the hour divided by the parking lot capacity of 5,000 parking spaces. Running times are averages for the lot calculated by weighting the averages at each gate by the traffic volumes at that gate. Averaged speeds were calculated from the average running times and trip lengths given for "all gates" in Table B-1.

## Table C-1. TRAFFIC AND PARKING CHARACTERISTICS AT THE LIBERTY TREE MALL

December 10, 1973

| Time of day | In | Out | Total | Excess | Capacity (%) | Running time (sec) | Average speed (mph) |
|---|---|---|---|---|---|---|---|
| 0800-0900 | 569 | 180 | 749 | 389 | | | |
| 0900-1000 | 1,689 | 357 | 2,046 | 1,721 | | | |
| 100-1100 | 2,071 | 1,079 | 3,150 | 2,713 | 44 | 134 | 13.5 |
| 1100-1200 | 1,893 | 1,789 | 3,682 | 2,817 | 55 | 130 | 12.6 |
| 1200-1300 | 1,871 | 1,966 | 3,837 | 2,722 | 55 | 110 | 12.7 |
| 1300-1400 | 1,836 | 2,008 | 3,844 | 2,550 | 52.5 | 133 | 15.0 |
| 1400-1500 | 1,621 | 1,868 | 3,489 | 2,304 | 48.5 | 120 | 14.0 |
| 1500-1600 | 1,692 | 1,823 | 3,515 | 2,173 | 44.5 | 97 | 11.3 |
| 1600-1700 | 1,625 | 1,929 | 3,554 | 1,869 | 40 | 96 | 11.6 |
| 1700-1800 | 1,811 | 1,839 | 3,650 | 1,841 | 37 | 123 | 12.7 |
| 1800-1900 | 2,448 | 1,626 | 4,074 | 2,663 | 45 | 90 | 12.3 |
| 1900-2000 | 2,979 | 1,964 | 4,943 | 3,677 | 63.5 | 157 | 9.1 |
| 2000-2100 | 1,844 | 2,536 | 4,380 | 2,985 | 67 | 161 | 8.8 |
| 2100-2200 | 822 | 2,367 | 3,189 | 1,440 | 44.5 | 117 | 10.5 |
| 2200-2230- | 230 | 1,217 | 1,447 | 453 | | | |
| 2230-2300 | 82 | 435 | 517 | 100 | | | |
| December 11, 1973 | | | | | | | |
| 0800-0900 | 536 | 171 | 707 | 365 | | | |
| 0900-1000 | 1,265 | 334 | 1,599 | 1,297 | | | |
| 1000-1100 | 1,695 | 932 | 2,627 | 2,059 | 33.5 | 103 | 15.4 |
| 1100-1200 | 1,567 | 1,477 | 3,044 | 2,150 | 42 | 116 | 10.6 |
| 1200-1300 | 1,657 | 1,660 | 3,317 | 2,147 | 43 | 122 | 12.8 |
| 1300-1400 | 1,634 | 1,848 | 3,482 | 1,933 | 41 | 99 | 12.6 |
| 1400-1500 | 1,534 | 1,695 | 3,229 | 1,771 | 37 | 96 | 13.5 |
| 1500-1600 | 1,559 | 1,633 | 3,192 | 1,698 | 34.5 | 123 | 11.7 |
| 1600-1700 | 1,573 | 1,692 | 3,265 | 1,579 | 33 | 92 | 13.0 |
| 1700-1800 | 1,655 | 1,628 | 3,283 | 1,605 | 32 | 95 | 11.5 |
| 1800-1900 | 2,346 | 1,411 | 3,757 | 2,540 | 41.5 | 108 | 13.0 |
| 1900-2000 | 2,775 | 1,736 | 4,511 | 3,579 | 61.5 | 135 | 10.2 |
| 2000-2100 | 1,988 | 2,405 | 4,393 | 3,162 | 67.5 | 153 | 9.1 |
| 2100-2200 | 967 | 2,449 | 3,416 | 1,681 | 48.5 | 117 | 10.4 |
| 2200-2230 | 212 | 1,235 | 1,447 | 658 | | | |
| 2230-2300 | 88 | 646 | 734 | 100 | | | |

## Table C-1 (cont). TRAFFIC AND PARKING CHARACTERISTICS AT THE LIBERTY TREE MALL

### December 12, 1973

| Time of day | In | Out | Total | Excess | Capacity (%) | Running time (sec) | Average speed (mph) |
|---|---|---|---|---|---|---|---|
| 0800-0900 | 614 | 190 | 804 | 424 | | | |
| 0900-1000 | 1,175 | 315 | 1,490 | 1,283 | | | |
| 1000-1100 | 1,659 | 842 | 2,501 | 2,100 | 34 | 130 | 11.9 |
| 1100-1200 | 1,591 | 1,455 | 3,046 | 2,236 | 43.5 | 118 | 12.7 |
| 1200-1300 | 1,895 | 1,727 | 3,622 | 2,404 | 46.5 | 116 | 11.9 |
| 1300-1400 | 1,698 | 1,883 | 3,581 | 2,219 | 46 | 111 | 9.6 |
| 1400-1500 | 1,619 | 1,645 | 3,264 | 2,193 | 44 | 109 | 10.9 |
| 1500-1600 | 1,653 | 1,590 | 3,243 | 2,256 | 44.5 | 113 | 12.2 |
| 1600-1700 | 1,606 | 1,814 | 3,420 | 2,048 | 43 | 129 | 11.0 |
| 1700-1800 | 1,759 | 1,734 | 3,493 | 2,073 | 41 | 106 | 10.1 |
| 1800-1900 | 2,221 | 1,524 | 3,745 | 2,770 | 48 | 111 | 11.5 |
| 1900-2000 | 2,723 | 1,734 | 4,457 | 3,758 | 65 | 160 | 8.8 |
| 2000-2100 | 1,816 | 2,229 | 4,045 | 3,345 | 71 | 146 | 7.5 |
| 2100-2200 | 885 | 2,216 | 3,101 | 2,014 | 53.5 | 99 | 11.0 |
| 2200-2230 | 226 | 1,132 | 1,358 | 1,108 | | | |
| 2230-2300 | 90 | 1,098 | 1,188 | 100 | | | |

### December 13, 1973

| Time of day | In | Out | Total | Excess | Capacity (%) | Running time (sec) | Average speed (mph) |
|---|---|---|---|---|---|---|---|
| 0800-0900 | 490 | 168 | 658 | 322 | | | |
| 0900-1000 | 1,147 | 513 | 1,660 | 956 | | | |
| 1000-1100 | 1,645 | 1,004 | 2,649 | 1,597 | 25.5 | 112 | 13.6 |
| 1100-1200 | 1,583 | 1,646 | 3,229 | 1,533 | 31.5 | 107 | 15.1 |
| 1200-1300 | 1,782 | 1,739 | 3,521 | 1,576 | 31.5 | 102 | 12.2 |
| 1300-1400 | 1,630 | 1,599 | 3,229 | 1,608 | 32 | 109 | 11.5 |
| 1400-1500 | 1,537 | 1,533 | 3,075 | 1,612 | 32 | 101 | 11.6 |
| 1500-1600 | 1,700 | 1,797 | 3,497 | 1,514 | 31 | 105 | 13.8 |
| 1600-1700 | 1,757 | 1,837 | 3,594 | 1,434 | 29.5 | 126 | 10.9 |
| 1700-1800 | 2,012 | 1,733 | 3,745 | 1,714 | 31.5 | 101 | 13.2 |
| 1800-1900 | 2,395 | 1,653 | 4,048 | 2,456 | 41.5 | 113 | 12.4 |
| 1900-2000 | 2,737 | 2,073 | 4,810 | 3,120 | 55.5 | 144 | 11.5 |
| 2000-2100 | 1,900 | 2,324 | 4,224 | 2,696 | 58 | 137 | 11.7 |
| 2100-2200 | 1,007 | 2,433 | 3,440 | 1,270 | 39.5 | 99 | 12.7 |
| 2200-2230 | 185 | 1,023 | 1,208 | 432 | | | |
| 2230-2300 | 101 | 433 | 534 | 100 | | | |

## Table C-1 (cont). TRAFFIC AND PARKING CHARACTERISTICS AT THE LIBERTY TREE MALL

December 14, 1973

| Time of day | In | Out | Total | Excess | Capacity (%) | Running time (sec) | Average speed (mph) |
|---|---|---|---|---|---|---|---|
| 0800-0900 | 567 | 202 | 769 | 365 | | | |
| 0900-1000 | 1,146 | 310 | 1,456 | 1,201 | | | |
| 1000-1100 | 1,571 | 897 | 2,468 | 1,875 | 31 | 133 | 10.2 |
| 1100-1200 | 1,591 | 1,453 | 3,044 | 2,013 | 39 | 123 | 9.8 |
| 1200-1300 | 1,716 | 1,611 | 3,327 | 2,118 | 41 | 133 | 11.6 |
| 1300-1400 | 1,571 | 1,759 | 3,330 | 1,930 | 40.5 | 129 | 8.9 |
| 1400-1500 | 1,579 | 1,551 | 3,130 | 1,958 | 39 | 150 | 10.8 |
| 1500-1600 | 1,651 | 1,521 | 3,172 | 2,089 | 40.5 | 118 | 10.1 |
| 1600-1700 | 1,761 | 1,970 | 3,731 | 1,880 | 40 | 121 | 11.0 |
| 1700-1800 | 1,936 | 1,768 | 3,704 | 2,048 | 39.5 | 118 | 9.6 |
| 1800-1900 | 2,462 | 1,676 | 4,138 | 2,834 | 49 | 128 | 11.2 |
| 1900-2000 | 2,946 | 2,084 | 5,030 | 3,696 | 65.5 | 134 | 9.0 |
| 2000-2100 | 2,246 | 2,598 | 4,844 | 3,344 | 70.5 | 188 | 7.1 |
| 2100-2200 | 1,230 | 2,733 | 3,963 | 1,841 | 52 | 142 | 10.6 |
| 2200-2230 | 257 | 1,499 | 1,756 | 599 | | | |
| 2230-2300 | 125 | 624 | 749 | 100 | | | |

December 15, 1973

| Time of day | In | Out | Total | Excess | Capacity (%) | Running time (sec) | Average speed (mph) |
|---|---|---|---|---|---|---|---|
| 0800-0900 | 551 | 214 | 765 | 337 | | | |
| 0900-1000 | 1,955 | 552 | 2,507 | 1,739 | | | |
| 1000-1100 | 2,731 | 1,758 | 4,489 | 2,712 | 44.5 | 115 | 10.1 |
| 1100-1200 | 2,595 | 2,465 | 5,060 | 2,842 | 55.5 | 114 | 10.1 |
| 1200-1300 | 2,892 | 2,223 | 5,115 | 3,511 | 63.5 | 198 | 9.4 |
| 1300-1400 | 3,233 | 2,620 | 5,853 | 4,124 | 76 | 215 | 8.3 |
| 1400-1500 | 3,142 | 2,946 | 6,088 | 4,320 | 84 | 223 | 8.6 |
| 1500-1600 | 2,731 | 3,174 | 5,905 | 3,877 | 82 | 224 | 5.5 |
| 1600-1700 | 2,263 | 3,150 | 5,413 | 2,989 | 69 | 145 | 7.3 |
| 1700-1800 | 2,089 | 2,611 | 4,700 | 2,468 | 54.5 | 138 | 10.7 |
| 1800-1900 | 2,109 | 2,118 | 4,227 | 2,459 | 49 | 115 | 8.3 |
| 1900-2000 | 2,575 | 1,994 | 4,569 | 3,040 | 55 | 118 | 10.3 |
| 2000-2100 | 1,996 | 2,184 | 4,180 | 2,852 | 59 | 186 | 7.6 |
| 2100-2200 | 1,146 | 2,341 | 3,487 | 1,657 | 45 | 117 | 10.9 |
| 2200-2230 | 347 | 1,267 | 1,614 | 736 | | | |
| 2230-2300 | 165 | 801 | 966 | 100 | | | |

### Table C-1 (cont). TRAFFIC AND PARKING CHARACTERISTICS AT THE LIBERTY TREE MALL

December 18, 1973

| Time of day | In | Out | Total | Excess | Capacity (%) | Running time (sec) | Average speed (mph) |
|---|---|---|---|---|---|---|---|
| 0800-0900 | 616 | 286 | 902 | 330 | | | |
| 0900-1000 | 1,406 | 461 | 1,867 | 1,275 | | | |
| 1000-1100 | 2,001 | 1,060 | 3,061 | 2,216 | 35 | 109 | 9.6 |
| 1100-1200 | 2,044 | 1,758 | 3,802 | 2,502 | 47 | 126 | 10.9 |
| 1200-1300 | 2,047 | 2,144 | 4,191 | 2,405 | 49 | 159 | 9.6 |
| 1300-1400 | 2,051 | 2,334 | 4,385 | 2,121 | 45 | 104 | 8.9 |
| 1400-1500 | 1,723 | 2,110 | 3,833 | 1,734 | 38.5 | 109 | 9.6 |
| 1500-1600 | 1,798 | 2,039 | 3,837 | 1,493 | 32.5 | 146 | 7.6 |
| 1600-1700 | 1,764 | 2,014 | 3,778 | 1,243 | 27.5 | 116 | 11.4 |
| 1700-1800 | 1,921 | 1,733 | 3,654 | 1,431 | 27 | 102 | 13.1 |
| 1800-1900 | 2,476 | 1,636 | 4,112 | 2,270 | 37 | 140 | 11.7 |
| 1900-2000 | 3,094 | 1,974 | 5,068 | 3,391 | 56.5 | 157 | 6.5 |
| 2000-2100 | 2,337 | 2,558 | 4,895 | 3,170 | 65.5 | 175 | 8.5 |
| 2100-2200 | 1,078 | 2,575 | 3,653 | 1,673 | 48 | 142 | 10.1 |
| 2200-2230 | 208 | 1,363 | 1,571 | 517 | | | |
| 2230-2300 | 95 | 512 | 607 | 100 | | | |

December 19, 1973

| Time of day | In | Out | Total | Excess | Capacity (%) | Running time (sec) | Average speed (mph) |
|---|---|---|---|---|---|---|---|
| 0800-0900 | 484 | 154 | 638 | 330 | | | |
| 0900-1000 | 1,356 | 353 | 1,709 | 1,333 | | | |
| 1000-1100 | 1,990 | 1,243 | 3,233 | 2,080 | 34.5 | 114 | 11.5 |
| 100-1200 | 1,897 | 1,909 | 3,806 | 2,069 | 41.5 | 89 | 10.7 |
| 1200-1300 | 2,104 | 2,275 | 4,379 | 1,898 | 39.5 | 109 | 12.0 |
| 1300-1400 | 2,161 | 2,424 | 4,585 | 1,635 | 35.5 | 126 | 10.2 |
| 1400-1500 | 1,852 | 2,218 | 4,070 | 1,269 | 29 | 103 | 11.2 |
| 1500-1600 | 1,963 | 2,092 | 4,055 | 1,140 | 24 | 121 | 11.5 |
| 1600-1700 | 1,942 | 2,078 | 4,020 | 1,004 | 21.5 | 120 | 10.1 |
| 1700-1800 | 2,021 | 2,140 | 4,161 | 885 | 19 | 99 | 11.9 |
| 1800-1900 | 2,723 | 1,702 | 4,425 | 1,906 | 28 | 107 | 14.1 |
| 900-2000 | 3,182 | 2,078 | 5,260 | 3,010 | 49 | 167 | 9.4 |
| 000-2100 | 2,487 | 2,531 | 5,018 | 2,966 | 59.5 | 169 | 6.1 |
| 2100-2200 | 1,307 | 2,608 | 3,915 | 1,666 | 46 | 104 | 12.2 |
| 2200-2230 | 249 | 1,375 | 1,624 | 540 | | | |
| 2230-2300 | 169 | 609 | 778 | 100 | | | |

## Table C-1 (cont). TRAFFIC AND PARKING CHARACTERISTICS AT THE LIBERTY TREE MALL

December 20, 1973

| Time of day | In | Out | Total | Excess | Capacity (%) | Running time (sec) | Average speed (mph) |
|---|---|---|---|---|---|---|---|
| 0800-0900 | 558 | 293 | 851 | 265 | | | |
| 0900-1000 | 1,399 | 573 | 1,972 | 1,090 | | | |
| 1000-1100 | 1,936 | 1,239 | 3,175 | 1,788 | 29 | 121 | 9.7 |
| 1100-1200 | 2,061 | 1,947 | 4,008 | 1,901 | 37 | 99 | 11.4 |
| 1200-1300 | 2,171 | 2,160 | 4,331 | 1,913 | 38 | 125 | 10.9 |
| 1300-1400 | 1,910 | 2,046 | 3,956 | 1,777 | 37 | 112 | 12.0 |
| 1400-1500 | 1,829 | 2,028 | 3,857 | 1,578 | 34 | 100 | 12.0 |
| 1500-1600 | 2,007 | 2,094 | 4,101 | 1,491 | 31 | 120 | 11.9 |
| 1600-1700 | 1,976 | 2,083 | 4,059 | 1,384 | 29 | 95 | 12.8 |
| 1700-1800 | 2,166 | 2,041 | 4,207 | 1,509 | 29 | 104 | 13.2 |
| 1800-1900 | 2,526 | 2,001 | 4,527 | 2,034 | 35.5 | 143 | 9.8 |
| 1900-2000 | 3,089 | 2,127 | 5,216 | 2,996 | 50.5 | 167 | 7.3 |
| 2000-2100 | 2,499 | 2,553 | 5,052 | 2,942 | 59.5 | 169 | 8.9 |
| 2100-2200 | 1,425 | 2,759 | 4,184 | 1,607 | 45.5 | 122 | 12.3 |
| 2200-2230 | 390 | 1,200 | 1,590 | 797 | | | |
| 2230-2300 | 121 | 818 | 939 | 100 | | | |

December 21, 1973

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 0800-0900 | 562 | 214 | 776 | 348 | | | |
| 0900-1000 | 1,398 | 434 | 1,832 | 1,311 | | | |
| 1000-1100 | 1,905 | 1,250 | 3,155 | 1,966 | 32.5 | 110 | 11.4 |
| 1100-1200 | 2,056 | 2,042 | 4,098 | 1,980 | 39.5 | 105 | 11.1 |
| 1200-1300 | 2,215 | 2,032 | 4,247 | 2,163 | 41.5 | 134 | 11.2 |
| 1300-1400 | 2,132 | 2,027 | 4,159 | 2,268 | 44 | 144 | 9.1 |
| 1400-1500 | 2,082 | 2,039 | 4,121 | 2,311 | 45.5 | 128 | 11.0 |
| 1500-1600 | 2,268 | 2,272 | 4,540 | 2,308 | 46 | 111 | 11.9 |
| 1600-1700 | 2,395 | 2,394 | 4,789 | 2,309 | 46 | 132 | 11.0 |
| 1700-1800 | 2,206 | 2,607 | 4,813 | 1,908 | 42 | 101 | 12.5 |
| 1800-1900 | 2,415 | 2,032 | 4,447 | 2,291 | 42 | 112 | 14.5 |
| 1900-2000 | 3,224 | 2,140 | 5,364 | 3,375 | 56.5 | 162 | 9.2 |
| 2000-2100 | 2,654 | 2,687 | 5,341 | 3,341 | 67 | 130 | 8.3 |
| 2100-2200 | 1,767 | 3,041 | 4,808 | 2,067 | 54 | 131 | 10.1 |
| 2200-2230 | 379 | 1,721 | 2,100 | 725 | | | |
| 2230-2300 | 200 | 825 | 1,025 | 100 | | | |

## Table C-1 (cont). TRAFFIC AND PARKING CHARACTERISTICS AT THE LIBERTY TREE MALL

### December 22, 1973

| Time of day | In | Out | Total | Excess | Capacity (%) | Running time (sec) | Average speed (mph) |
|---|---|---|---|---|---|---|---|
| 0800-0900 | 527 | 243 | 770 | 284 | | | |
| 0900-1000 | 1,882 | 659 | 2,541 | 1,507 | | | |
| 1000-1100 | 3,009 | 2,086 | 5,095 | 2,430 | 39.5 | 134 | 12.2 |
| 1100-1200 | 3,240 | 2,915 | 6,155 | 2,755 | 52 | 146 | 13.4 |
| 1200-1300 | 3,457 | 3,281 | 6,738 | 2,931 | 57 | 324 | 7.2 |
| 1300-1400 | 3,522 | 3,246 | 6,768 | 3,207 | 61.5 | 141 | 9.8 |
| 1400-1500 | 3,410 | 3,406 | 6,816 | 3,211 | 64 | 255 | 5.4 |
| 1500-1600 | 3,052 | 3,742 | 6,794 | 2,521 | 57 | 141 | 7.6 |
| 1600-1700 | 2,573 | 3,203 | 5,776 | 1,892 | 44 | 140 | 14.1 |
| 1700-1800 | 2,190 | 2,513 | 4,703 | 1,569 | 34.5 | 162 | 8.9 |
| 1800-1900 | 2,102 | 2,076 | 4,178 | 1,594 | 31.5 | 114 | 10.5 |
| 1900-2000 | 2,477 | 1,894 | 4,341 | 2,177 | 38 | 110 | 11.7 |
| 2000-2100 | 2,261 | 2,118 | 4,379 | 2,320 | 45 | 179 | 9.8 |
| 2100-2200 | 1,559 | 2,532 | 4,091 | 1,347 | 36.5 | 151 | 10.4 |
| 2200-2230 | 386 | 1,049 | 1,435 | 684 | | | |
| 2230-2300 | 167 | 751 | 918 | 100 | | | |

### December 24, 1973

| Time of day | In | Out | Total | Excess | Capacity (%) | Running time (sec) | Average speed (mph) |
|---|---|---|---|---|---|---|---|
| 0800-0900 | 720 | 326 | 1,046 | 394 | | | |
| 0900-1000 | 1,615 | 764 | 2,415 | 1,282 | | | |
| 1000-1100 | 3,701 | 2,328 | 6,029 | 2,654 | 39.5 | 150 | 9.4 |
| 1100-1200 | 3,793 | 3,587 | 7,380 | 2,860 | 55 | 165 | 9.9 |
| 1200-1300 | 3,428 | 3,495 | 6,923 | 2,793 | 56.5 | 142 | 9.3 |
| 1300-1400 | 3,328 | 3,454 | 6,782 | 2,667 | 54.5 | 157 | 7.7 |
| 1400-1500 | 3,033 | 3,989 | 7,022 | 1,712 | 43.5 | 204 | 7.6 |
| 1500-1600 | 2,458 | 3,022 | 5,480 | 1,148 | 28.5 | 153 | 10.3 |
| 1600-1700 | 1,896 | 2,328 | 4,224 | 715 | 18.5 | 92 | 12.8 |
| 1700-1800 | 1,232 | 1,847 | 3,079 | 100 | 8.0 | 126 | 9.6 |

# APPENDIX D

## INTERSECTION CAPACITIES

Figures D-1 through D-4 are intersection sketches of the four entrance/exit gates at the Liberty Tree Mall showing vehicle capacities (level of service E). These capacities were calculated using a methodology described in The Highway Capacity Manual, Highway Research Board, Special Report No. 87 and are based on the physical characteristics of the intersection, the environmental setting, and traffic control. The values are estimates of the maximum vehicular flow that can be metered through each intersection in one hour.

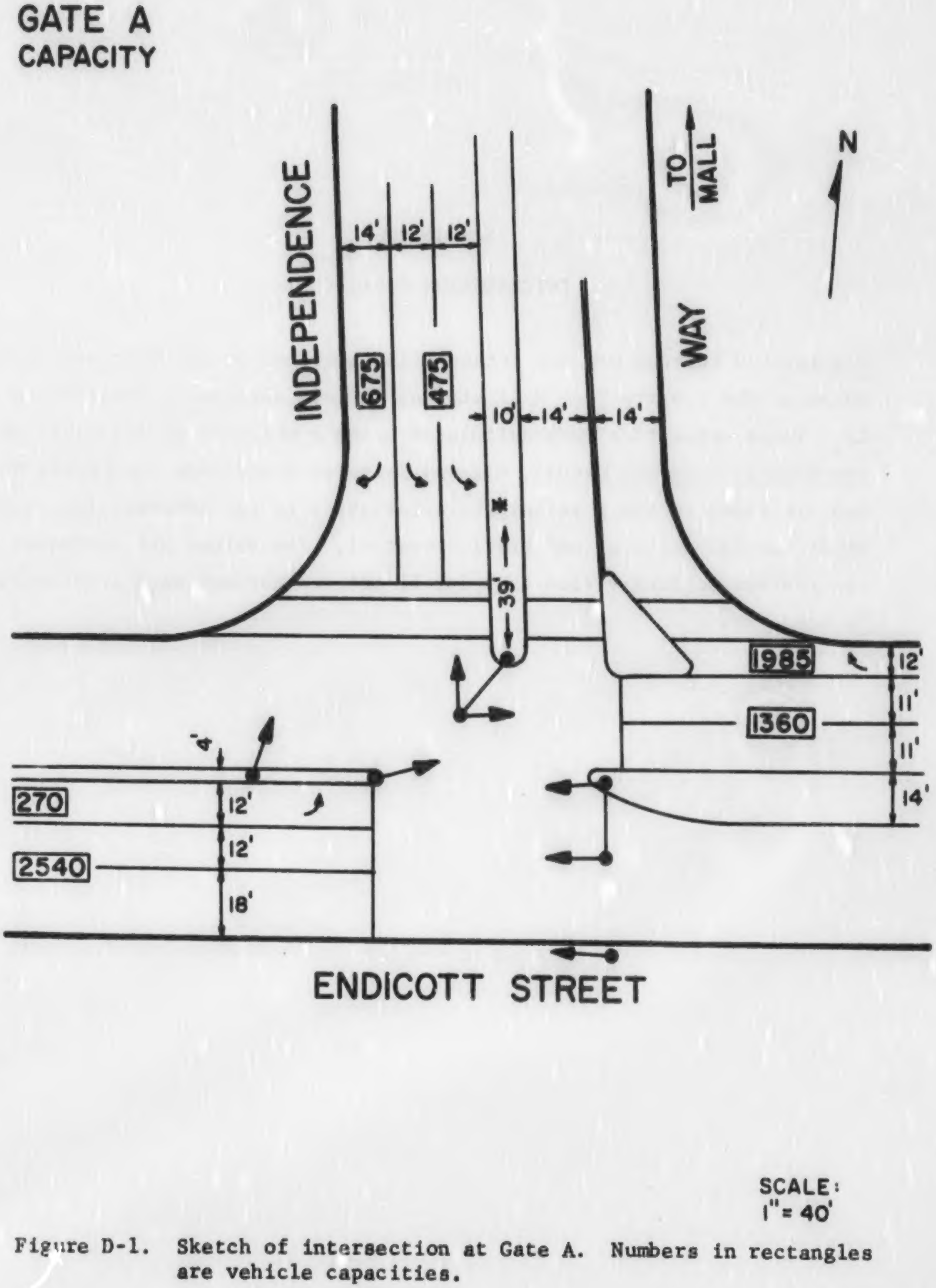
GATE A
CAPACITY
INDEPENDENCE
WAY
TO MALL
N
14'
12'
12'
675
475
10'
14'
14'
39'
1985
12'
11'
1360
11'
14'
4'
270
12'
2540
12'
18'
ENDICOTT STREET
SCALE: 1" = 40'

Figure D-1. Sketch of intersection at Gate A. Numbers in rectangles are vehicle capacities.

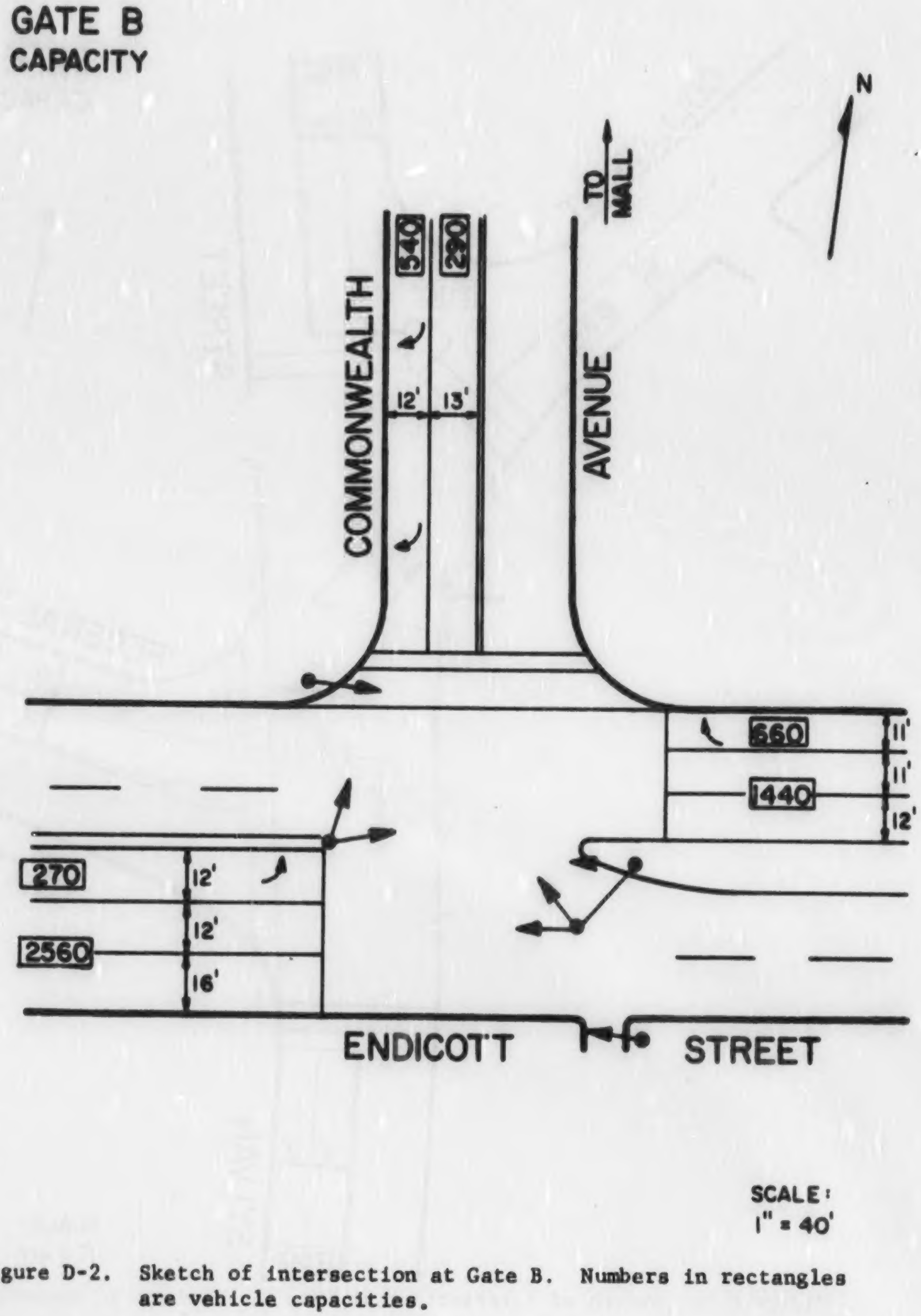
GATE B
CAPACITY
N
TO MALL
COMMONWEALTH
AVENUE
540
290
12'
13'
660
1440
11'
11'
12'
270
2560
12'
12'
16'
ENDICOTT
STREET
SCALE:
1" = 40'

Figure D-2. Sketch of intersection at Gate B. Numbers in rectangles are vehicle capacities.

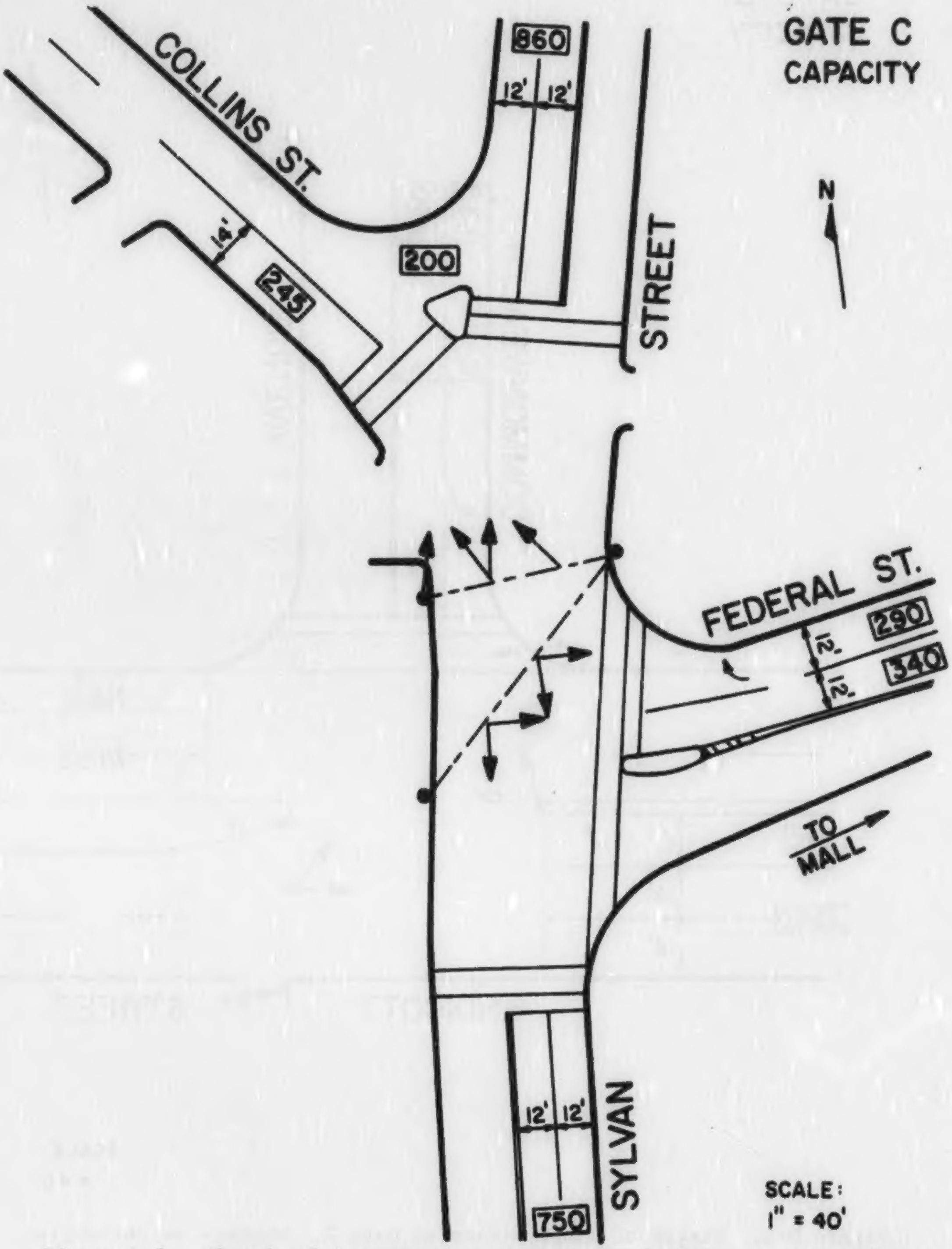
GATE C
CAPACITY
N
COLLINS ST.
860
12'
12'
14'
245
200
STREET
FEDERAL ST.
12'
290
12'
340
TO MALL
12'
12'
SYLVAN
750
SCALE:
1" = 40'

Figure D-3. Sketch of intersection at Gate C. Numbers in rectangles are vehicle capacities.

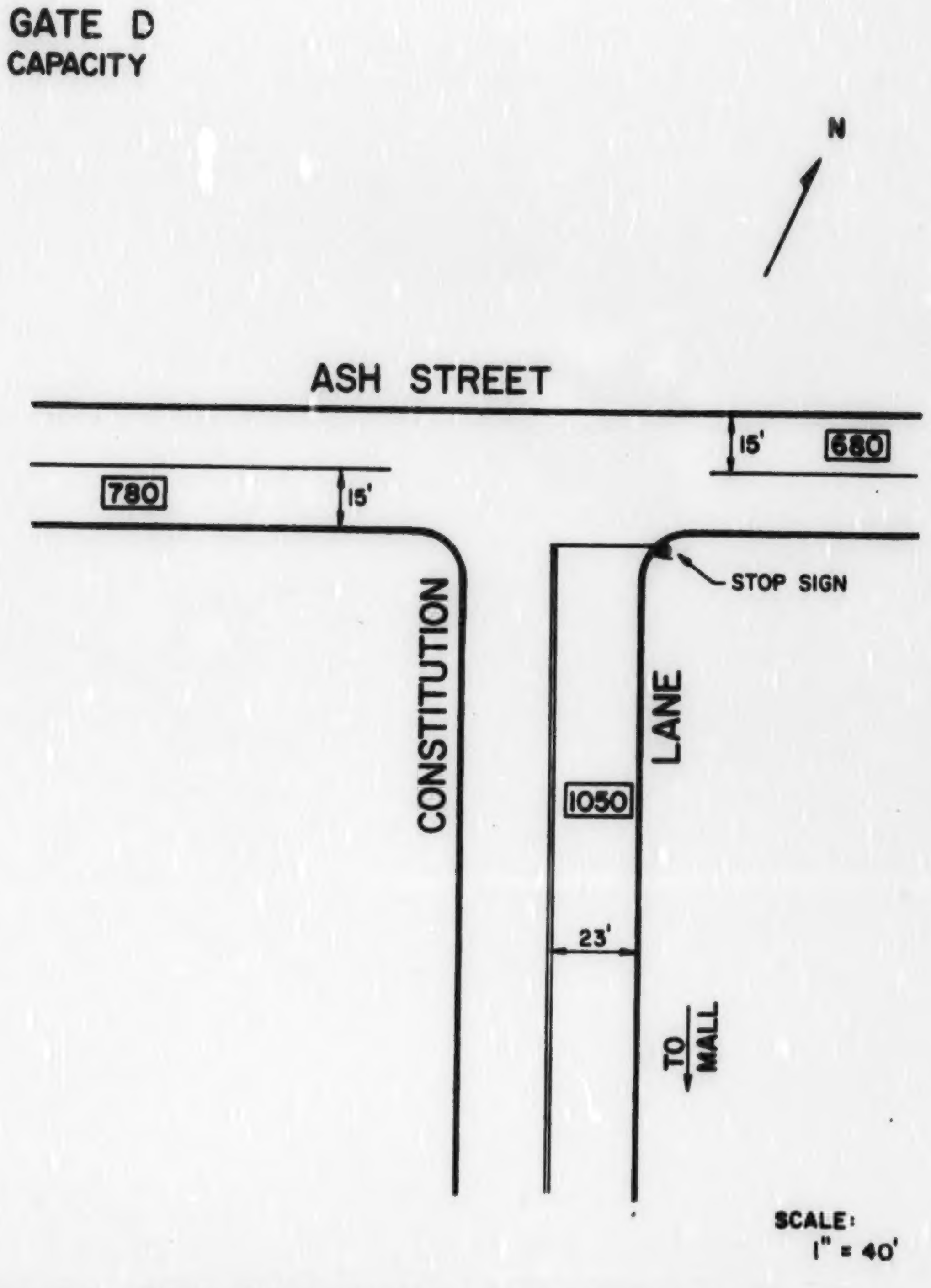
GATE D
CAPACITY
N
ASH STREET
15'
680
780
15'
STOP SIGN
CONSTITUTION
LANE
1050
23'
TO MALL
SCALE:
1" = 40'

Figure D-4. Sketch of intersection at Gate D. Numbers in rectangles are vehicle capacities.

# APPENDIX E

## METEOROLOGICAL DATA

Table E-1 lists hourly meteorological data recorded at the Liberty Tree Shopping Center during the field program and stability estimates made using the classification scheme described by Turner (Workbook of Atmospheric Dispersion Estimates, USPHS Publication No. AP-26, 1971). Wind speed and direction observations were made at the top of an 18-foot mast mounted on the roof of the shopping center mall. Ambient temperature measurements were made at a height of 1-2 meters above ground. Sky cover was taken from WBAN forms obtained from the National Weather Service at Logan Airport, Boston. Wind data in parentheses are estimates made using the WBAN data.

Table E-1. METEOROLOGICAL DATA RECORDED AT THE LIBERTY TREE MALL

| Date | Hour (EST) | Temperature (°F) | Precipitation | Wind direction (deg) | Wind speed (m/sec) | Wind speed (knots) | Insolation class | Sky cover (tenths) | Net radiation index | Stability |
|---|---|---|---|---|---|---|---|---|---|---|
| 12-10 | 0800-0900 | | | 230 | 4.0 | 7.8 | | 10 | 0 | D |
| | 0900-1000 | | | 250 | 3.5 | 6.8 | 1 | 10 | 0 | D |
| | 1000-1100 | | | 250 | (4.0) | (7.8) | 2 | 10 | 0 | (D) |
| | 1100-1200 | | | 250 | (3.5) | (6.8) | 2 | 8 | 1 | (D) |
| | 1200-1300 | | | 270 | 4.5 | 8.7 | 2 | 5.5 | 1 | D |
| | 1300-1400 | | | 250 | 4.0 | 7.8 | 2 | 5.5 | 1 | D |
| | 1400-1500 | | | 250 | 2.5 | 4.9 | 1 | 6 | 1 | D |
| | 1500-1600 | | | 260 | 2.0 | 3.9 | 1 | 7 | 1 | D |
| | 1600-1700 | 44 | | 260 | 2.5 | 3.9 | | 9 | -1 | E |
| | 1700-1800 | | | 280 | 1.0 | 1.9 | | 10 | 0 | D |
| | 1800-1900 | | | 270 | 1.0 | 1.9 | | 10 | 0 | D |
| | 1900-2000 | | | 230 | 1.0 | 1.9 | | 10 | 0 | D |
| | 2000-2100 | | | 180 | 1.0 | 1.9 | | 7 | -1 | F |
| | 2100-2200 | 40 | | 210 | 1.5 | 2.9 | | 4 | -2 | F |
| | 2200-2300 | | | 280 | 1.0 | 1.9 | | 4 | -2 | F |
| 12-11 | 0800-0900 | | rain | (20) | 2.0 | 3.9 | | 10 | 0 | D |
| | 0900-1000 | 40 | rain | (350) | 2.0 | 3.9 | 1 | 10 | 0 | D |
| | 1000-1100 | 39 | rain | 340 | 2.0 | 3.9 | 2 | 10 | 0 | D |
| | 1100-1200 | | rain | 320 | 2.5 | 4.9 | 2 | 10 | 0 | D |
| | 1200-1300 | | rain | 330 | 2.5 | 4.9 | 2 | 10 | 0 | D |
| | 1300-1400 | 38 | rain | 340 | 3.0 | 5.8 | 2 | 10 | 0 | D |
| | 1400-1500 | 39 | | 310 | 2.0 | 3.9 | 1 | 10 | 0 | D |
| | 1500-1600 | 41 | | 320 | 1.5 | 2.9 | 1 | 7.5 | 1 | C |
| | 1600-1700 | 41 | | 310 | 3.0 | 5.8 | | 6 | -1 | E |
| | 1700-1800 | 37 | | 310 | 3.5 | 6.8 | | 8 | -1 | D |
| | 1800-1900 | 37 | | 320 | 3.5 | 6.8 | | 9 | -1 | D |
| | 1900-2000 | | | 320 | 3.0 | 5.8 | | 6.5 | -1 | E |
| | 2000-2100 | 35 | | 310 | 3.0 | 5.8 | | 3 | -2 | F |
| | 2100-2200 | 33 | | 310 | 3.0 | 5.8 | | 1 | -2 | F |
| | 2200-2300 | | | 320 | 2.0 | 3.9 | | 0 | -2 | F |

Table E-1 (cont). METEOROLOGICAL DATA RECORDED AT THE LIBERTY TREE MALL

| Date | Hour (EST) | Temperature (°F) | Precipitation | Wind direction (deg) | Wind speed (m/sec) | Wind speed (knots) | Isolation class | Sky cover (tenths) | Net radiation index | Stability |
|---|---|---|---|---|---|---|---|---|---|---|
| 12-12 | 0800-0900 | | | 330 | 3.5 | 6.8 | | 4 | -2 | E |
| | 0900-1000 | | | 320 | 4.0 | 7.8 | 1 | 2.5 | 1 | D |
| | 1000-1100 | | | 320 | 4.5 | 8.7 | 2 | 2.5 | 2 | C |
| | 1100-1200 | 40 | | 310 | 4.0 | 7.8 | 2 | 2.5 | 2 | C |
| | 1200-1300 | 42 | | 310 | 3.0 | 5.8 | 2 | 1 | 2 | C |
| | 1300-1400 | 41 | | 310 | (4.0) | (7.8) | 2 | 0 | 2 | (C) |
| | 1400-1500 | | | 310 | (4.0) | (7.8) | 1 | 0 | 1 | (D) |
| | 1500-1600 | 40 | | 310 | (4.0) | (7.8) | 1 | 0 | 1 | (D) |
| | 1600-1700 | | | 300 | 1.5 | 2.9 | | 0 | -2 | F |
| | 1700-1800 | 33 | | 310 | 1.5 | 2.9 | | 0 | -2 | F |
| | 1800-1900 | 34 | | 300 | 1.0 | 1.9 | | 0 | -2 | F |
| | 1900-2000 | 33 | | 290 | 1.0 | 1.9 | | 0 | -2 | F |
| | 2000-2100 | | | 300 | 1.0 | 1.9 | | 0.5 | -2 | F |
| | 2100-2200 | 31 | | 320 | 0.5 | 1.0 | | 0.5 | -2 | F |
| | 2200-2300 | 27 | | 290 | (0.5) | (1.0) | | 0 | -2 | F |
| 12-13 | 0800-0900 | | | 330 | 1.0 | 1.9 | | 2 | -2 | F |
| | 0900-1000 | 33 | | 40 | (1.5) | (2.9) | 1 | 0 | 1 | (C) |
| | 1000-1100 | | | 140 | (2.0) | (3.9) | 2 | 0 | 2 | (C) |
| | 1100-1200 | 43 | | 140 | (2.0) | (3.9) | 2 | 0 | 2 | (C) |
| | 1200-1300 | 46 | | 180 | (2.5) | (4.9) | 2 | 3.5 | 2 | (C) |
| | 1300-1400 | | | 170 | (2.0) | (3.9) | 2 | 8.5 | 2 | (C) |
| | 1400-1500 | | | 170 | (2.0) | (3.9) | 1 | 10 | 0 | (D) |
| | 1500-1600 | | | 160 | (2.5) | (4.9) | 1 | 10 | 0 | (D) |
| | 1600-1700 | 38 | | 150 | 2.5 | 4.9 | | 10 | -1 | E |
| | 1700-1800 | | | 150 | 2.5 | 4.9 | | 10 | -1 | E |
| | 1800-1900 | 38 | | 140 | 3.5 | 6.8 | | 10 | -1 | D |
| | 1900-2000 | 39 | | 160 | 3.0 | 5.8 | | 10 | -1 | E |
| | 2000-2100 | | | 150 | 2.5 | 4.9 | | 10 | -1 | E |
| | 2100-2200 | 39 | | 150 | 2.0 | 3.9 | | 10 | -1 | E |
| | 2200-2300 | 43 | | 140 | 3.5 | 6.8 | | 10 | -1 | D |

Table E-1 (cont). METEOROLOGICAL DATA RECORDED AT THE LIBERTY TREE MALL

| Date | Hour (EST) | Temperature ($^{o}$F) | Precipitation | Wind direction (deg) | Wind speed (m/sec) | Wind speed (knots) | Insolation class | Sky cover (tenths) | Net radiation index | Stability |
|---|---|---|---|---|---|---|---|---|---|---|
| 12-14 | 0800-0900 | | | 120 | 8.5 | 16.5 | | 10 | 0 | D |
| | 0900-1000 | | rain | 120 | 8.5 | 16.5 | 1 | 10 | 0 | D |
| | 1000-1100 | 49 | rain | 130 | 7.5 | 14.6 | 2 | 10 | 0 | D |
| | 1100-1200 | 50 | rain | 130 | 6.5 | 12.6 | 2 | 10 | 0 | D |
| | 1200-1300 | 50 | rain | 120 | 6.5 | 12.6 | 2 | 10 | 0 | D |
| | 1300-1400 | 50 | rain | 140 | 7.0 | 13.6 | 2 | 10 | 0 | D |
| | 1400-1500 | 52 | | 170 | 2.0 | 3.9 | 1 | 10 | 0 | D |
| | 1500-1600 | 51 | | 140 | 1.0 | 1.9 | 1 | 10 | 0 | D |
| | 1600-1700 | 52 | | 260 | 2.0 | 3.9 | | 10 | 0 | D |
| | 1700-1800 | | | 270 | 4.0 | 7.8 | | 8 | -1 | D |
| | 1800-1900 | 48 | | 270 | 4.5 | 8.7 | | 4 | -2 | E |
| | 1900-2000 | | | 280 | 5.5 | 10.7 | | 1.5 | -2 | D |
| | 2000-2100 | 44 | | 280 | 4.5 | 8.7 | | 1 | -2 | E |
| | 2100-2200 | 43 | | 280 | 4.5 | 8.7 | | 0.5 | -2 | E |
| | 2200-2300 | 42 | | 290 | 4.5 | 8.7 | | 0.5 | -2 | E |
| 12-15 | 0800-0900 | | | 300 | 4.0 | 7.8 | | 2.5 | -2 | E |
| | 0900-1000 | 36 | | 300 | 4.0 | 7.8 | 1 | 2 | 1 | D |
| | 1000-1100 | 38 | | 300 | 3.5 | 6.8 | 2 | 2 | 2 | C |
| | 1100-1200 | 41 | | 290 | 3.5 | 6.8 | 2 | 3 | 2 | C |
| | 1200-1300 | 45 | | 280 | 3.0 | 5.8 | 2 | 5.5 | 1 | D |
| | 1300-1400 | 47 | | 280 | 3.0 | 5.8 | 2 | 7.5 | 2 | C |
| | 1400-1500 | 45 | | 290 | 2.5 | 4.9 | 1 | 9 | 1 | D |
| | 1500-1600 | 42 | | 310 | 2.0 | 3.9 | 1 | 8.5 | 1 | D |
| | 1600-1700 | 40 | | 280 | 2.0 | 3.9 | | 6 | -1 | E |
| | 1700-1800 | 36 | | 300 | 2.0 | 3.9 | | 7.5 | -1 | E |
| | 1800-1900 | 35 | | 300 | 2.0 | 3.9 | | 8.5 | -1 | E |
| | 1900-2000 | 34 | | 300 | 2.0 | 3.9 | | 6.5 | -1 | E |
| | 2000-2100 | 32 | | 290 | 1.5 | 2.9 | | 7 | -1 | F |
| | 2100-2200 | 32 | | 280 | 2.0 | 3.9 | | 9 | -1 | E |
| | 2200-2300 | 31 | | 290 | 2.0 | 3.9 | | 10 | 0 | D |

Table E-1 (cont). METEOROLOGICAL DATA RECORDED AT THE LIBERTY TREE MALL

| Date | Hour (EST) | Temperature (°F) | Precipitation | Wind direction (deg) | Wind speed (m/sec) | Wind speed (knots) | Insolation class | Sky cover (tenths) | Net radiation index | Stability |
|---|---|---|---|---|---|---|---|---|---|---|
| 12-17 | 0800-0900 | | rain | 10 | (2.0) | (3.9) | | 10 | 0 | (D) |
| | 0900-1000 | | rain | 40 | (2.5) | (4.9) | 1 | 10 | 0 | (D) |
| | 1000-1100 | | rain | 310 | (2.5) | (4.9) | 2 | 10 | 0 | (D) |
| | 1100-1200 | | rain | 330 | (1.5) | (2.9) | 2 | 10 | 0 | (D) |
| | 1200-1300 | | rain | 280 | 1.5 | 2.9 | 2 | 10 | 0 | D |
| | 1300-1400 | | rain | 190 | 4.0 | 7.8 | 2 | 10 | 0 | D |
| | 1400-1500 | | rain | 140 | 6.5 | 12.6 | 1 | 10 | 0 | D |
| | 1500-1600 | | rain | 180 | 5.5 | 10.7 | 1 | 10 | 0 | D |
| | 1600-1700 | | rain | 270 | 2.0 | 3.9 | | 10 | 0 | D |
| | 1700-1800 | | rain | 270 | 1.5 | 2.9 | | 10 | 0 | D |
| | 1800-1900 | | | 260 | 1.5 | 2.9 | | 10 | 0 | D |
| | 1900-2000 | | | 210 | 6.5 | 12.6 | | 10 | 0 | D |
| | 2000-2100 | | | 210 | 4.5 | 8.7 | | 6 | -1 | D |
| | 2100-2200 | | | 210 | 2.0 | 3.9 | | 6 | -1 | D |
| | 2200-2300 | | | 220 | 3.5 | 6.8 | | 10 | 0 | D |
| 12-18 | 0800-0900 | | | 270 | 6.5 | 12.6 | | 0 | -2 | D |
| | 0900-1000 | | | 280 | 7.0 | 13.6 | 1 | 0 | 1 | D |
| | 1000-1100 | 13 | | 280 | 6.5 | 12.6 | 2 | 0 | 2 | D |
| | 1100-1200 | 17 | | 280 | 7.0 | 13.6 | 2 | 0 | 2 | D |
| | 1200-1300 | 22 | | 290 | 6.5 | 12.6 | 2 | 0 | 2 | D |
| | 1300-1400 | 25 | | 290 | 7.0 | 13.6 | 2 | 0 | 2 | D |
| | 1400-1500 | 26 | | 290 | 5.5 | 10.7 | 1 | 0 | 1 | D |
| | 1500-1600 | 26 | | 290 | 6.5 | 12.6 | 1 | 0 | 1 | D |
| | 1600-1700 | | | 290 | 4.5 | 8.7 | | 0 | -2 | E |
| | 1700-1800 | 25 | | 290 | 3.5 | 6.8 | | 0 | -2 | E |
| | 1800-1900 | 20 | | 280 | 4.0 | 7.8 | | 0 | -2 | E |
| | 1900-2000 | 20 | | 280 | 4.5 | 8.7 | | 0 | -2 | E |
| | 2000-2100 | | | 300 | 4.5 | 8.7 | | 0 | -2 | E |
| | 2100-2200 | | | 310 | 4.5 | 8.7 | | 0 | -2 | E |
| | 2200-2300 | 15 | | 310 | 5.0 | 9.7 | | 0 | -2 | E |

Table E-1 (cont). METEOROLOGICAL DATA RECORDED AT THE LIBERTY TREE MALL

| Date | Hour (EST) | Temperature (°F) | Precipitation | Wind direction (deg) | Wind speed (m/sec) | Wind speed (knots) | Insolation class | Sky cover (tenths) | Net radiation index | Stability |
|---|---|---|---|---|---|---|---|---|---|---|
| 12-19 | 0800-0900 |  |  | 320 | 2.0 | 3.9 |  | 0 | -2 | F |
|  | 0900-1000 |  |  | 340 | 2.0 | 3.9 | 1 | 0 | 1 | D |
|  | 1000-1100 | 19 |  | 340 | 2.0 | 3.9 | 2 | 0 | 2 | C |
|  | 1100-1200 | 21 |  | 300 | 2.0 | 3.9 | 2 | 0 | 2 | C |
|  | 1200-1300 |  |  | 290 | 2.0 | 3.9 | 2 | 0 | 2 | C |
|  | 1300-1400 | 21 |  | 290 | 1.5 | 2.9 | 2 | 0 | 2 | C |
|  | 1400-1500 | 19 |  | 270 | 1.5 | 2.9 | 1 | 1.5 | 1 | C |
|  | 1500-1600 | 19 |  | 260 | 1.5 | 2.9 | 1 | 6.5 | 1 | C |
|  | 1600-1700 | 18 |  | 280 | 1.5 | 2.9 |  | 10 | 0 | D |
|  | 1700-1800 | 18 |  | 290 | 1.5 | 2.9 |  | 10 | 0 | D |
|  | 1800-1900 | 19 |  | 250 | 1.0 | 1.9 |  | 10 | 0 | D |
|  | 1900-2000 | 20 |  | 240 | 1.0 | 1.9 |  | 10 | 0 | D |
|  | 2000-2100 | 20 |  | 240 | 1.0 | 1.9 |  | 10 | 0 | D |
|  | 2100-2200 | 22 |  | 300 | 1.0 | 1.9 |  | 10 | 0 | D |
|  | 2200-2300 |  |  | 360 | 1.0 | 1.9 |  | 10 | 0 | D |
| 12-20 | 0800-0900 |  |  | 350 | 1.5 | 2.9 |  | 10 | 0 | D |
|  | 0900-1000 | 25 |  | 20 | 2.0 | 3.9 | 1 | 10 | 0 | D |
|  | 1000-1100 | 27 |  | 30 | 2.0 | 3.9 | 2 | 10 | 0 | D |
|  | 1100-1200 | 28 |  | 40 | 2.0 | 3.9 | 2 | 10 | 0 | D |
|  | 1200-1300 | 30 |  | 20 | 2.0 | 3.9 | 2 | 10 | 0 | D |
|  | 1300-1400 | 34 |  | 20 | 2.0 | 3.9 | 2 | 10 | 0 | D |
|  | 1400-1500 | 34 |  | 350 | 1.0 | 1.9 | 1 | 10 | 0 | D |
|  | 1500-1600 | 34 |  | 290 | 1.5 | 2.9 | 1 | 10 | 0 | D |
|  | 1600-1700 | 34 |  | 320 | 1.5 | 2.9 |  | 10 | 0 | D |
|  | 1700-1800 | 34 |  | 330 | 1.0 | 1.9 |  | 10 | 0 | D |
|  | 1800-1900 | 33 |  | 300 | 1.5 | 2.9 |  | 10 | 0 | D |
|  | 1900-2000 |  |  | 360 | 1.0 | 1.9 |  | 10 | 0 | D |
|  | 2000-2100 | 37 |  | 190 | 1.0 | 1.9 |  | 10 | -1 | F |
|  | 2100-2200 | 46 |  | 140 | 3.0 | 5.8 |  | 10 | -1 | E |
|  | 2200-2300 | 47 |  | 130 | 3.0 | 5.8 |  | 10 | -1 | E |

Table E-1 (cont). METEOROLOGICAL DATA RECORDED AT THE LIBERTY TREE MALL

| Date | Hour (EST) | Temperature (°F) | Precipitation | Wind direction (deg) | Wind speed (m/sec) | Wind speed (knots) | Insolation class | Sky cover (tenths) | Net radiation index | Stability |
|---|---|---|---|---|---|---|---|---|---|---|
| 12-21 | 0800-0900 | 58 |  | 150 | 6.0 | 11.7 |  | 10 | 0 | D |
|  | 0900-1000 | 58 |  | 160 | 6.0 | 11.7 | 1 | 10 | 0 | D |
|  | 1000-1100 |  |  | 120 | 4.5 | 8.7 | 2 | 10 | 0 | D |
|  | 1100-1200 |  |  | 120 | 4.5 | 8.7 | 2 | 10 | 0 | D |
|  | 1200-1300 |  |  | 120 | 6.0 | 11.7 | 2 | 10 | 0 | D |
|  | 1300-1400 |  |  | 140 | 7.5 | 14.6 | 2 | 10 | 0 | D |
|  | 1400-1500 | 58 |  | 160 | 6.5 | 12.6 | 1 | 10 | 0 | D |
|  | 1500-1600 |  |  | 170 | 6.0 | 11.7 | 1 | 10 | 0 | D |
|  | 1600-1700 | 57 |  | 170 | 6.5 | 12.6 |  | 9 | -1 | D |
|  | 1700-1800 | 56 |  | 170 | 7.0 | 13.6 |  | 6 | -1 | D |
|  | 1800-1900 | 54 |  | 170 | 7.5 | 14.6 |  | 4 | -2 | D |
|  | 1900-2000 | 51 | rain | 170 | 8.0 | 15.5 |  | 5.5 | -1 | D |
|  | 2000-2100 | 49 |  | 190 | 10.0 | 19.4 |  | 8 | -1 | D |
|  | 2100-2200 | 45 |  | 190 | 8.0 | 15.5 |  | 9.5 | -1 | D |
|  | 2200-2300 | 43 |  | 230 | 7.5 | 14.6 |  | 10 | 0 | D |
| 12-22 | 0800-0900 |  |  | 260 | 5.0 | 9.7 |  | 0.5 | -2 | E |
|  | 0900-1000 | 25 |  | 270 | 6.5 | 12.6 | 1 | 0 | 1 | D |
|  | 1000-1100 | 27 |  | 280 | 6.5 | 12.6 | 2 | 0 | 2 | D |
|  | 1100-1200 | 29 |  | 290 | 7.0 | 13.6 | 2 | 0 | 2 | D |
|  | 1200-1300 | 30 |  | 300 | 6.5 | 12.6 | 2 | 0 | 2 | D |
|  | 1300-1400 | 31 |  | 300 | 6.5 | 12.6 | 2 | 0 | 2 | D |
|  | 1400-1500 | 31 |  | 290 | 6.5 | 12.6 | 1 | 0 | 1 | D |
|  | 1500-1600 | 30 |  | 290 | 5.5 | 10.7 | 1 | 0 | 1 | D |
|  | 1600-1700 | 28 |  | 290 | 4.0 | 7.8 |  | 0 | -2 | E |
|  | 1700-1800 | 27 |  | 280 | 3.0 | 5.8 |  | 0 | -2 | F |
|  | 1800-1900 | 27 |  | 270 | 3.5 | 6.8 |  | 1 | -2 | E |
|  | 1900-2000 | 26 |  | 270 | 4.0 | 7.8 |  | 4.5 | -1 | D |
|  | 2000-2100 | 26 |  | 260 | 4.0 | 7.8 |  | 8.5 | -1 | D |
|  | 2100-2200 | 26 |  | 260 | 3.5 | 6.8 |  | 10 | -1 | D |
|  | 2200-2300 |  |  | 260 | 2.5 | 4.9 |  | 10 | -1 | E |

Table E-1 (cont). METEOROLOGICAL DATA RECORDED AT THE LIBERTY TREE MALL

| Date | Hour (EST) | Temperature ($^oF$) | Precipitation | Wind direction (deg) | Wind speed (m/sec) | Wind speed (knots) | Insolation class | Sky cover (tenths) | Net radiation index | Stability |
|---|---|---|---|---|---|---|---|---|---|---|
| 12-24 | 0800-0900 | | | 320 | 5.0 | 9.7 | | 1.5 | -2 | E |
| | 0900-1000 | | | 320 | 5.0 | 9.7 | 1 | 3 | 1 | D |
| | 1000-1100 | 25 | | 330 | 4.5 | 8.7 | 2 | 2 | 2 | C |
| | 1100-1200 | 30 | | 320 | 4.0 | 7.8 | 2 | 0.5 | 2 | C |
| | 1200-1300 | 30 | | 310 | 3.5 | 6.8 | 2 | 0 | 2 | C |
| | 1300-1400 | 31 | | 320 | 3.5 | 6.8 | 2 | 0 | 2 | C |
| | 1400-1500 | 31 | | 330 | 3.0 | 5.8 | 1 | 0 | 1 | D |
| | 1500-1600 | 29 | | 300 | 2.5 | 4.9 | 1 | 0 | 1 | D |
| | 1600-1700 | 27 | | 310 | 2.0 | 3.9 | | 0 | -2 | F |
| | 1700-1800 | | | 300 | 2.0 | 3.9 | | 0 | -2 | F |
| | 1800-1900 | | | 300 | 2.0 | 3.9 | | 0 | -2 | F |

# APPENDIX F

# CO CONCENTRATIONS

Table F-1 lists average 1-hour carbon monoxide concentrations observed at the five monitoring sites during the field program. The average concentrations were determined from the chart records by weighting individual data points (one per 3 seconds) by eye. The precision with which these average estimates could be made was a function of the variability of the individual data points recorded during the averaging period. At low concentrations the chart averages could be determined to about 0.5 ppm, while at high concentrations the averaging error was estimated to be about ±10 percent. For ease of reporting, concentrations are listed in tenths of a ppm through Table F-1.

Table F-1. AVERAGE 1-HOUR CARBON MONOXIDE CONCENTRATIONS (PPM)

| Time of day (EST) | December 10, 1973 | | | | |
|---|---|---|---|---|---|
| | No. 1 | No. 2 | No. 3 | No. 4 | No. 5 |
| 1000-1100 | | | | | |
| 1100-1200 | | | | | |
| 1200-1300 | 2.9 | 1.0 | 1.6 | 2.6 | |
| 1300-1400 | 2.7 | 1.1 | 1.0 | 1.4 | |
| 1400-1500 | 2.8 | 1.1 | 1.0 | 1.7 | |
| 1500-1600 | 4.6 | 1.1 | 1.0 | 3.5 | |
| 1600-1700 | 7.0 | 1.2 | 1.0 | 3.5 | |
| 1700-1800 | 8.4 | 3.9 | | 4.3 | |
| 1800-1900 | 24.7 | 6.8 | | 4.3 | |
| 1900-2000 | 20.4 | 8.5 | | 7.2 | 4.4 |
| 2000-2100 | 14.5 | 6.0 | | 6.4 | 2.6 |
| 2100-2200 | 19.1 | 6.4 | | 5.9 | 2.6 |
| 2200-2230 | 14.6 | 6.9 | | 9.6 | 6.4 |

| Time of day (EST) | December 11, 1973 | | | | |
|---|---|---|---|---|---|
| | No. 1 | No. 2 | No. 3 | No. 4 | No. 5 |
| 1000-1100 | 4.5 | | | 1.9 | 0.5 |
| 1100-1200 | 1.6 | 0.8 | | 1.5 | 0.5 |
| 1200-1300 | 2.2 | 0.8 | | 1.8 | 0.5 |
| 1300-1400 | 3.7 | 0.8 | | 2.3 | |
| 1400-1500 | 4.4 | 0.8 | | 2.4 | |
| 1500-1600 | 6.6 | 0.8 | | 1.9 | 0.9 |
| 1600-1700 | 3.1 | 1.6 | | 2.2 | 0.9 |
| 1700-1800 | 3.7 | 0.5 | | 2.3 | |
| 1800-1900 | 3.2 | 1.6 | | 2.7 | |
| 1900-2000 | 4.7 | 2.2 | | 4.2 | |
| 2000-2100 | 5.7 | 2.1 | | 3.3 | |
| 2100-2200 | 5.8 | 1.8 | | 3.1 | |
| 2200-2230 | 8.8 | 1.3 | | 3.4 | |

Table F-1 (cont). AVERAGE 1-HOUR CARBON MONOXIDE CONCENTRATIONS (PPM)

| Time of day (EST) | December 12, 1973 | | | | |
|---|---|---|---|---|---|
| | No. 1 | No. 2 | No. 3 | No. 4 | No. 5 |
| 1000-1100 | | | | | 1.2 |
| 1100-1200 | 2.1 | 0.5 | 0.9 | 1.0 | 2.2 |
| 1200-1300 | 2.0 | 0.5 | 0.6 | 1.9 | 2.0 |
| 1300-1400 | 1.8 | 0.5 | 0.9 | 2.4 | 2.0 |
| 1400-1500 | 0 | 0.3 | 0.6 | 1.7 | 1.4 |
| 1500-1600 | 4.6 | 0.6 | 0.7 | 1.5 | 0.7 |
| 1600-1700 | 4.8 | 2.6 | 2.1 | 1.5 | 1.8 |
| 1700-1800 | 6.7 | 4.2 | 2.1 | 4.0 | 3.4 |
| 1800-1900 | 8.1 | 6.2 | 5.2 | 5.8 | 4.6 |
| 1900-2000 | 8.3 | 4.3 | 6.5 | 6.9 | 2.3 |
| 2000-2100 | 10.3 | 3.8 | 5.4 | 6.0 | 2.7 |
| 2100-2200 | 25.0 | 4.2 | 3.1 | 5.6 | 2.0 |
| 2200-2230 | 14.1 | 5.0 | 8.7 | 11.5 | 11.2 |

| Time of day (EST) | December 13, 1973 | | | | |
|---|---|---|---|---|---|
| | No. 1 | No. 2 | No. 3 | No. 4 | No. 5 |
| 1000-1100 | | | 2.9 | 3.2 | 1.6 |
| 1100-1200 | | 2.6 | 2.9 | 1.0 | 1.7 |
| 1200-1300 | 6.4 | 1.3 | 2.4 | 1.5 | 1.7 |
| 1300-1400 | 5.1 | 0.6 | 2.0 | 1.4 | 1.7 |
| 1400-1500 | 6.3 | 0.6 | 3.0 | 1.6 | 1.7 |
| 1500-1600 | 7.5 | 1.8 | 3.0 | 2.7 | 2.2 |
| 1600-1700 | 8.7 | 2.4 | 3.5 | 4.2 | 1.8 |
| 1700-1800 | 8.7 | 2.3 | 3.0 | 3.8 | 2.7 |
| 1800-1900 | 8.6 | 2.3 | 3.6 | 3.2 | 3.5 |
| 1900-2000 | 8.0 | 4.0 | 3.3 | 3.2 | 2.6 |
| 2000-2100 | 11.4 | 4.1 | 4.8 | 3.7 | 3.4 |
| 2100-2200 | 9.9 | 4.1 | 3.8 | 2.8 | 2.5 |
| 2200-2230 | 8.6 | 6.1 | 6.8 | 2.8 | 0.4 |

Table F-1 (cont). AVERAGE 1-HOUR CARBON MONOXIDE CONCENTRATIONS (PPM)

| Time of day (EST) | December 14, 1973 | | | | |
|---|---|---|---|---|---|
| | No. 1 | No. 2 | No. 3 | No. 4 | No. 5 |
| 1000-1100 | 2.8 | | | 0.9 | |
| 1100-1200 | 2.8 | | | 0.9 | |
| 1200-1300 | 3.1 | | | 1.4 | |
| 1300-1400 | 3.7 | | | 1.2 | |
| 1400-1500 | 17.6 | 3.3 | | 2.8 | |
| 1500-1600 | 23.0 | 10.6 | | 7.5 | |
| 1600-1700 | 21.2 | 10.6 | | 11.6 | |
| 1700-1800 | 3.0 | 1.7 | | 2.6 | |
| 1800-1900 | 2.4 | 1.4 | 0.5 | 2.8 | |
| 1900-2000 | 1.8 | 1.1 | 1.0 | 2.8 | |
| 2000-2100 | 1.8 | 0.3 | | 3.8 | |
| 2100-2200 | 1.9 | 0.6 | | 2.9 | |
| 2200-2230 | 4.4 | 1.1 | | 4.7 | |

| Time of day (EST) | December 15, 1973 | | | | |
|---|---|---|---|---|---|
| | No. 1 | No. 2 | No. 3 | No. 4 | No. 5 |
| 1000-1100 | 4.0 | 1.3 | 0.8 | 2.4 | 0.4 |
| 1100-1200 | 3.4 | 1.0 | 2.2 | 2.4 | 0.8 |
| 1200-1300 | 3.7 | 0.8 | 1.0 | 2.6 | 0.8 |
| 1300-1400 | 2.0 | 0.5 | 1.5 | 3.3 | [illegible] |
| 1400-1500 | 6.1 | 0.8 | 1.1 | 2.4 | 0.8 |
| 1500-1600 | 12.1 | 1.0 | 4.0 | 3.1 | 0.8 |
| 1600-1700 | 9.4 | 0.5 | 4.3 | 3.8 | |
| 1700-1800 | 11.1 | 0.8 | 2.6 | 3.3 | |
| 1800-1900 | 7.4 | 1.6 | 2.2 | 3.1 | |
| 1900-2000 | 6.1 | 1.8 | 3.3 | 3.8 | |
| 2000-2100 | 9.4 | 1.9 | | 3.8 | 1.6 |
| 2100-2200 | 6.1 | 1.6 | 1.1 | 3.3 | 2.0 |
| 2200-2230 | 9.4 | 1.6 | 0.5 | 2.4 | 4.0 |

Figure F-1 (cont). AVERAGE 1-HOUR CARBON MONOXIDE CONCENTRATIONS (PPM)

| Time of day (EST) | December 18, 1973 | | | | |
|---|---|---|---|---|---|
| | No. 1 | No. 2 | No. 3 | No. 4 | No. 5 |
| 1000-1100 | | | | | |
| 1100-1200 | 1.5 | 0.8 | | 1.5 | |
| 1200-1300 | 1.8 | 0.5 | | 1.7 | |
| 1300-1400 | 1.5 | 0.3 | | 2.0 | |
| 1400-1500 | 1.5 | 0.8 | | 2.5 | |
| 1500-1600 | 1.1 | 0.8 | | 2.5 | |
| 1600-1700 | 2.3 | 1.1 | | 2.1 | |
| 1700-1800 | 1.9 | 1.1 | | 3.1 | |
| 1800-1900 | 2.0 | 1.2 | | 2.6 | |
| 1900-2000 | 1.6 | 1.2 | | 3.7 | |
| 2000-2100 | 3.2 | 1.2 | | 4.0 | |
| 2100-2200 | 8.0 | 0.6 | | 1.6 | |
| 2200-2230 | 7.3 | 0.6 | | 2.7 | |

| Time of day (EST) | December 19, 1973 | | | | |
|---|---|---|---|---|---|
| | No. 1 | No. 2 | No. 3 | No. 4 | No. 5 |
| 1000-1100 | | | | | |
| 1100-1200 | 6.4 | 0.5 | 0.7 | 1.5 | 1.1 |
| 1200-1300 | 6.4 | 0.5 | 1.0 | 1.5 | 2.2 |
| 1300-1400 | 7.7 | 1.1 | 1.0 | 1.0 | 1.6 |
| 1400-1500 | 7.1 | 1.6 | 0.5 | 1.5 | 2.2 |
| 1500-1600 | 10.3 | 1.1 | 1.0 | 2.0 | 2.3 |
| 1600-1700 | 7.7 | 1.3 | 1.0 | 1.5 | 2.9 |
| 1700-1800 | 14.1 | 1.6 | 1.0 | 1.5 | 2.3 |
| 1800-1900 | 10.3 | 1.6 | 1.6 | 2.5 | 3.0 |
| 1900-2000 | 12.8 | 1.6 | 1.6 | 3.5 | 3.0 |
| 2000-2100 | 14.1 | 2.2 | 2.4 | 4.5 | 3.0 |
| 2100-2200 | 20.5 | 2.8 | 1.9 | 3.5 | 3.1 |
| 2200-2230 | 20.5 | 1.7 | | 2.5 | |

Table F-1 (cont). AVERAGE 1-HOUR CARBON MONOXIDE CONCENTRATIONS (PPM)

| Time of day (EST) | December 20, 1973 | | | | |
|---|---|---|---|---|---|
| | No. 1 | No. 2 | No. 3 | No. 4 | No. 5 |
| 1000-1100 | 7.6 | 3.0 | | | |
| 1100-1200 | 5.5 | 3.0 | 2.7 | 2.5 | 1.5 |
| 1200-1300 | 8.9 | 3.0 | 5.4 | 4.5 | 1.5 |
| 1300-1400 | 6.8 | 3.0 | 2.7 | 8.5 | 1.0 |
| 1400-1500 | 11.6 | 2.9 | 3.3 | 2.5 | 1.0 |
| 1500-1600 | 4.8 | 2.3 | 4.0 | 3.0 | 1.5 |
| 1600-1700 | 7.4 | 2.9 | 2.0 | 3.4 | 1.8 |
| 1700-1800 | 12.1 | 2.6 | 3.6 | 3.7 | 1.8 |
| 1800-1900 | 6.7 | 2.9 | 3.2 | 3.9 | 2.1 |
| 1900-2000 | 17.4 | 2.8 | 5.2 | 5.8 | 2.4 |
| 2000-2100 | 30.6 | 8.8 | 12.8 | 12.6 | 7.6 |
| 2100-2200 | 6.6 | 3.4 | 3.2 | 1.9 | 2.2 |
| 2200-2230 | 5.3 | 5.6 | 3.2 | | |

| Time of day (EST) | December 21, 1973 | | | | |
|---|---|---|---|---|---|
| | No. 1 | No. 2 | No. 3 | No. 4 | No. 5 |
| 1000-1100 | 3.0 | | 2.8 | 1.5 | 1.0 |
| 1100-1200 | 6.1 | | 4.0 | 2.0 | 1.8 |
| 1200-1300 | 7.2 | | 4.2 | 2.0 | 1.8 |
| 1300-1400 | 4.2 | | 3.0 | 2.0 | 1.6 |
| 1400-1500 | 3.7 | | 2.8 | 1.5 | 0.6 |
| 1500-1600 | 4.3 | | 1.9 | 1.5 | 0.8 |
| 1600-1700 | 6.6 | | 2.0 | 1.5 | 1.2 |
| 1700-1800 | | 1.6 | 2.0 | 2.1 | 1.8 |
| 1800-1900 | | 1.0 | 2.1 | 1.8 | 1.2 |
| 1900-2100 | | 1.0 | 2.9 | 1.6 | 0.9 |
| 2000-2100 | | 1.6 | | 2.1 | 0.6 |
| 2100-2200 | | 1.9 | | 2.9 | |
| 2200-2230 | | | | 3.2 | |

Table F-1 (cont). AVERAGE 1-HOUR CARBON MONOXIDE CONCENTRATIONS (PPM)

| Time of day (EST) | December 22, 1973 | | | | |
|---|---|---|---|---|---|
| | No. 1 | No. 2 | No. 3 | No. 4 | No. 5 |
| 1000-1100 | 2.5 | 1.6 | | 3.1 | |
| 1100-1200 | 1.8 | 1.1 | 2.4 | 2.1 | 1.2 |
| 1200-1300 | 2.0 | 0.8 | 2.5 | 2.6 | 1.2 |
| 1300-1400 | 2.0 | 0.8 | 2.0 | 2.1 | 1.2 |
| 1400-1500 | 2.5 | 0.5 | 2.7 | 2.7 | 1.2 |
| 1500-1600 | 4.0 | 0.8 | 2.8 | 2.7 | 1.3 |
| 1600-1700 | 5.0 | 1.0 | 2.5 | 3.8 | 2.3 |
| 1700-1800 | 7.0 | 0.8 | 3.0 | 3.8 | 2.3 |
| 1800-1900 | 2.5 | 2.5 | 3.0 | 2.2 | 2.7 |
| 1900-2000 | 3.0 | 0.8 | 3.1 | 2.5 | 2.7 |
| 2000-2100 | 3.5 | 1.0 | 4.8 | 3.3 | 2.1 |
| 2100-2200 | 5.4 | 1.0 | 4.1 | 3.4 | 1.4 |
| 2200-2230 | 3.9 | 1.0 | 2.6 | 3.4 | 1.1 |

| Time of day (EST) | December 24, 1973 | | | | |
|---|---|---|---|---|---|
| | No. 1 | No. 2 | No. 3 | No. 4 | No. 5 |
| 1000-1100 | 6.6 | 1.4 | | 1.8 | 0.8 |
| 1100-1200 | 6.8 | 0.9 | 1.2 | 1.6 | 0.6 |
| 1200-1300 | 6.0 | 0.7 | 1.0 | 0.8 | 0.3 |
| 1300-1400 | 7.1 | 0.5 | 1.0 | 0.3 | 0.3 |
| 1400-1500 | 7.2 | 0.2 | 0.7 | 0.3 | 0.3 |
| 1500-1600 | 4.2 | 0.2 | 0.3 | 0.8 | 0.6 |
| 1600-1700 | 10.8 | 0.7 | 0.7 | 1.2 | 0.6 |
| 1700-1800 | 7.2 | 2.0 | 1.1 | | |

## APPENDIX G

## SENSITIVITY ANALYSIS OF PROPOSED EPA METHODOLOGY

The methodology outlined in Section II provides a means for predicting the impact of a shopping center complex on CO concentrations. This appendix describes the sensitivity of the predictions to changes in the values of the input parameters.

A first approach might be to estimate the prediction sensitivity by differentiating the predicting equations (equations 1 to 7 in Section II) with respect to each of the input parameters. Doing this will give a series of sensitivity equations expressing, for each parameter, the sensitivity of the ultimate CO prediction to a unit change in the parameter. In each case the units of the expression will include the units of the parameter in question.

Since the dissimilar units for each expression would make comparisons of prediction sensitivities for different parameters a difficult task, a more promising approach may be to examine prediction sensitivities in terms of the precision of each input parameter. Under this approach we would aim to answer two questions: (1) If we know the precision of measurement of each of the input parameters, what is the resulting precision of the CO prediction developed from those parameters? and (2) What is the sensitivity of prediction precision to the precision of each of the parameters? The last question relates to the relative importance of the input parameters since it allows us to estimate how much the prediction precision will be improved by improving the precision of each of the parameters. By precision we refer to the relative error tolerances in a parameter so that, for example, we may state that parameter x = 0.75 ± 10%, where the 10% is the precision. This understanding of the term precision will hold throughout the sections that follow. The term sensitivity will refer to the change in precision of CO prediction for a given change in precision of an input parameter. For example, if traffic flow figures are precise to ±10%, what effect on prediction precision will be realized by obtaining traffic flow figures precise to ±5%?

In the sections that follow a methodology is developed for estimating prediction precision, given precision estimates for the input parameters. The equations for sensitivity of prediction precision to input parameter precision are also developed. The assumptions on which the analysis is based are delineated in the next section, and in the last section an example of the application of this methodology is presented.

## ASSUMPTION TO METHODOLOGY

Throughout the analysis that follows we have taken the predicted CO level as the dependent variable and each of the parameters (listed below) as independent variables. The analysis then proceeds to express the precision of the dependent variable in terms of the precision of each of the independent variables. The major assumptions on which this analysis is based are:

1. That measurement errors expressed by the precision of any variable are random and are normally distributed.
2. That these measurement errors are independent.

Neither of these assumptions is entirely valid; lack of independence is immediately apparent for factors which are actually interrelated. Two of these are the running time and the emission factor. The emission factor precision depends on the precision in average speed, which in turn depends on the running time (and distance). However, the assumptions are not unreasonable for the purpose of developing an idea of the relationships between the parameters and the CO predictions.

It should be noted that a further assumption implicit in the model is that of a constant meterology. The diffusion modeling aspects of the assessment methodology, being designed to estimate concentrations under extreme conditions only, assume specific meteorological conditions and further assume these conditions to remain invariant. Under the assumption of an invariant meteorology, the precision analysis and sensitivity analysis that follow are valid.

One final note on the analysis that follows. Since the assumptions on which this analysis is based are quite restrictive, the results should not be interpreted as absolute or as highly accurate precision and sensitivity assessments. They are intended, rather, to given an indication of the nature of the relationships that exist between parameters and between CO predictions and input parameters. Precisions and sensitivities developed from this methodology should be used to gain a feel for how the variables in the assessment model interrelate. They should not be interpreted as firm statements of error, precision or sensitivity.

## SENSITIVITY PARAMETERS

The input parameters required by the assessment model were listed in Section II of this report. Of these parameters, only those subject to statistical or measurement variation are included in the sensitivity and precision analyses. Other parameters such as shopping center area, number of parking spaces, etc., are precisely known and are not therefore of significance to the sensitivity and precision analyses. Still other parameters, such as meteorological variables, are implicity fixed in the assessment model and are therefore not included in the sensitivity and precision analyses, although they are clearly subject to statistical and measurement variation. The list of parameters included in the sensitivity and precision analyses is as follows:

1. Added vehicle running time due to traffic signals (C).
2. Auto emission factor (ef).
3. Background CO level (COB).
4. Base vehicle running time (BRT).
5. Correction factor for exceeded gate and/or parking capacity (cf).
6. Gate capacity (g).
7. Traffic flow at gate (T).
8. Traffic volume generated (V).

## SENSITIVITY AND PRECISION ANALYSIS METHODOLOGY

The analysis presented below is in two parts. First is the analysis of prediction precision and second is the analysis of precision sensitivity.

The problem of prediction precision is essentially that of analyzing the propagation of parameter precision estimates through the set of equations that represent the assessment methodology. These equations can be broken into sequences of sums and products and, since the precision of the sum or product of two imprecise numbers can be evaluated, it is relatively straightforward to derive the overall equation for prediction precision.

It is assumed that the precision of each parameter is reported as a "relative error"—i.e., a value plus or minus some percent of that value—and that some confidence level may be assumed for that error range. In other words, a full statement of precision of a parameter would be: there is an X percent confidence that the true value of the parameter lies within Y percent of the estimated (or measured) value. We apply the usual assumption that all errors approach a normal distribution, hence we can relate these estimates of precision to coefficients of variation. To do this we determine, from tabulations of the normal probability function, the number of standard deviations that correspond to the given percent confidence level (call this number k). Note also that the "absolute error" for a parameter is given by:

$$AE = \overline{X} \frac{E}{100} \qquad \text{(G-1)}$$

where $\overline{X}$ is the estimated value of the parameter and
E is the relative error associated with the parameter.

Now since this absolute error is equal to kS where S is the standard deviation of the distribution for that parameter, we get:

$$S = \frac{1}{k} \overline{X} \frac{E}{100} \qquad \text{(G-2)}$$

and the coefficient of variation for the error distribution is given by:

$$CV = \frac{S}{\overline{X}} = \frac{1}{k} \frac{E}{100} \qquad \text{(G-3)}$$

This relationship is important since it tells us that coefficients of variation can be derived from parameter precision estimates. Since the equations derived for propagation of errors (or compounding) are more conveniently expressed in terms of coefficients of variation, this in turn allows us to use them to derive the prediction error propagation relationships. The relationships are outlined below.

The Case of Summation or Subtraction

The precision of a sum of variables is as follows:

$$\text{Given } Z = X_1 + X_2 + X_3 \ldots$$

and $S_1$, $S_2$, $S_3$ . . . are the standard deviations in $X_1$, $S_2$, $X_3$ . . .

we have standard deviation in Z:

$$S_Z = \sqrt{S_1{}^2 + S_2{}^2 + S_3{}^2 \ldots} \qquad \text{(G-4)}$$

Dividing by $\overline{Z}$ gives:

$$\frac{S_Z}{\overline{Z}} = \sqrt{\left(\frac{S_1}{\overline{X}_1}\right)^2 \left(\frac{\overline{X}_1}{\overline{Z}}\right)^2 + \left(\frac{S_2}{\overline{X}_2}\right)^2 \left(\frac{\overline{X}_2}{\overline{Z}}\right)^2 \ldots} \qquad \text{(G-5)}$$

but since $\frac{S_Z}{\overline{Z}}$, $\frac{S_1}{\overline{X}_1}$, etc., are coefficients of variation we can substitute equation (G-3) to get:

$$E_Z = \sqrt{E_1{}^2\, A_1{}^2 + E_2{}^2\, A_2{}^2} \qquad \text{(G-6)}$$

where the E's are relative errors (precisions) and the A's are relative weights of each of the components of Z.

This equation expresses the expected precision of a sum of imprecise parameters. The same relationship holds when subtraction is involved.

he Case of Multiplication and Division

The precision of a product of random variables is as follows:

$$\text{Given } Z = X_1\, X_2\, X_3 \ldots$$

and again $S_1$, $S_2$, . . . are the standard deviations in the X's, then from the relationship:*

$$S_Z^{\,2} = \left(\frac{\partial Z}{\partial X_1} S_1\right)^2 + \left(\frac{\partial Z}{\partial X_2} S_2\right)^2 \ldots \qquad \text{(G-7)}$$

(under the assumption that the X's vary independently) we get:

$$S_Z^{\,2} = (\bar{X}_2\bar{X}_3 \ldots S_1)^2 + (\bar{X}_1\bar{X}_3 \ldots S_2)^2 + (\bar{X}_1\bar{X}_2\bar{X}_4 \ldots S_3)^2 \ldots \qquad \text{(G-8)}$$

by evaluating the derivatives at the mean values of the variables; dividing by $\bar{Z}^2$ gives:

$$\left(\frac{S_Z}{\bar{Z}}\right)^2 = \left(\frac{S_1}{\bar{X}_1}\right)^2 + \left(\frac{S_2}{\bar{X}_2}\right)^2 \ldots \qquad \text{(G-8)}$$

and, again, since $\frac{S_Z}{\bar{Z}}$, $\frac{S_1}{\bar{X}_1}$, etc., are coefficients of variation, we can substitute equation (G-3) to get:

$$E_Z = \sqrt{E_1^{\,2} + E_2^{\,2} + \ldots} \qquad \text{(G-9)}$$

where the E's are relative errors. This equation expresses the expected precision of a product of imprecise parameters. A similar derivation will show that the same relationship holds when division is involved.

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*This relationship is exact for continuous variables, while it is an approximation for discrete variables.

Hence equations (G-6) and (G-9) can be used, as illustrated in the next section, to evaluate the propagation of precision estimates through the equations of the assessment model.

The next problem is to estimate the sensitivity of prediction to each of the parameter precision estimates. Since precision estimating relationships are in the form of equations (G-6) and (G-9), these equations may be differentiated to provide the basic sensitivity relationships.

From equation (G-6) (precision in summation), the sensitivity of $E_Z$ (precision in Z) to $E_i$ (precision in parameter i) is:

$$\frac{\partial E_Z}{\partial E_i} = A_i^2 \frac{E_i}{E_Z} \tag{G-10}$$

where $A_i$ is the relative weight of the i$^{th}$ component in the summation to Z.

From equation (G-9) (precision in multiplication and division), the sensitivity of $E_Z$ to $E_i$ is:

$$\frac{\partial E_Z}{\partial E_i} = \frac{E_i}{E_Z} \tag{G-11}$$

hese basic sensitivity relationships (equations (G-10) and (G-11)) may be applied to the set of precision relationships developed (from equations (G-6) and (G-9)) for the prediction model. By application of the chain rule in evaluating derivitives, the sensivity of the CO prediction to each f the base parameters may be obtained. For example, if prediction presion is a function of $E_Z$ and, in turn, $E_Z$ is a function of $E_1$ (these functions being in the form of equations (G-6) and (G-9)), then the sens ivity of prediction precision to $E_1$ is obtained through the relationship:

$$\frac{\partial E_p}{\partial E_1} = \frac{\partial E_p}{\partial E_Z}\frac{\partial E_Z}{\partial E_1} \qquad \text{(G-12)}$$

**An example of the application of this analysis to the assessment methodology is presented in the next section, while in the section following that the full set of precision and sensitivity equations is presented.**

## APPLICATION OF SENSITIVITY AND PRECISION METHODOLOGY

As an example of the procedure followed in applying the sensitivity and precision relationships derived above, consider equation (2) of the assessment methodology. This equation is used to relate area wide emissions from the shopping complex to CO concentrations at a monitoring point. Area wide emissions are:

$$Q = \frac{ef \cdot V \cdot RT}{A}$$

Given the assumption of invariant meteorology, CO concentration at the monitoring point, due to area wide emissions, is directly proportional to Q. Hence:

$$COA = K \frac{ef \cdot V \cdot RT}{A} \qquad \text{(G-13)}$$

where COA is the CO concentration due to area wide emissions, and, under the assumption of invariant meteorology, K is some fixed and precise number.

A is the area of the shopping complex and is also assumed to be a known, precise number.

ef, V and RT (auto emission factor, traffic volume and running time per vehicle), on the other hand, are parameters subject to measurement error, since their values are estimated or measured from statistical samples. Hence, by equation (G-9), the relative error in a CO prediction is

$$E_{COA} = \sqrt{E_{ef}^{\;2} + E_{V}^{\;2} + E_{RT}^{\;2}} \qquad \text{(G-14)}$$

where $E_i$ represents a relative error in parameter i.

Now, by equation (G-11) the sensitivity of this CO prediction precision to, say, running time is:

$$\frac{\partial E_{COA}}{\partial E_{RT}} = \frac{E_{RT}}{E_{COA}} \qquad \text{(G-15)}$$

Next, the running time estimate that enters into equation (2) is given by equation (3):

$$RT = BRT + ART + C$$

where BRT is base running time. ART and C are added running times.

In this equation each parameter is, itself, a random variable having some measurement error. Thus, applying equation (G-6) the relative error in running time is given by:

$$E_{RT} = \sqrt{\left(E_{BRT}\,\frac{BRT}{RT}\right)^2 + \left(E_{ART}\,\frac{ART}{RT}\right)^2 + \left(E_C\,\frac{C}{RT}\right)^2}\;, \qquad \text{(G-16)}$$

and the estimate of $E_{RT}$ becomes an input to equations (G-14) and (G-15). Now consider, for example, the base running time (BRT) entered into equation (5). Using equation (G-10), the sensitivity of the relative error in total running time ($E_{RT}$) to that in the base running time ($E_{BRT}$) is found by:

$$\frac{\partial E_{RT}}{\partial E_{BRT}} = \left(\frac{BRT}{RT}\right)^2 \frac{E_{BRT}}{E_{RT}} . \qquad \text{(G-17)}$$

And now, by the chain rule of equation (G-12), we can estimate the sensitivity of the precision of predicted CO concentration (COA) to that of the parameter, base running time:

$$\frac{\partial E_{COA}}{\partial E_{BRT}} = \frac{\partial E_{COA}}{\partial E_{RT}} \frac{\partial E_{RT}}{\partial E_{BRT}} = \left(\frac{BRT}{RT}\right)^2 \frac{E_{BRT}}{E_{COA}} . \qquad \text{(G-18)}$$

Through the procedure illustrated above and outlined under "Sensitivity and Precision Analysis Methodology," the sensitivity of the model's prediction precision to measurement precision in each of the input parameters can be determined. These in turn provide a means of evaluating the sensitivity of the model's predictions to the key input parameters. In the next section the overall precision relationships and the key sensitivity relationships will be presented (without detailed derivation) and in the final section their application will be illustrated.

## PRECISION AND SENSITIVITY EQUATIONS

The above methodology has been applied to each of the key parameters listed under "Sensitivity Parameters" and it has been based on the assessment methodology equations of Section II. Thus sensitivities are referred to the total CO concentration estimated from all sources (background shopping center emissions and exit congestion). The overall error propagation equation for relative errors is first presented, followed by a presentation of sensitivities for each parameter.

### Relative Error of Prediction (Precision)

The total predicted CO concentration at a point is estimated by the model to be the sum of contributions from (1) background CO, (2) nearby line source emissions—i.e., queue of waiting cars, and (3) area wide emissions from the complex.

$$COT = COB + COL + COA$$

where COB is background CO concentration

COL is concentration attributable to emissions from a nearby line source

COA is concentration attributable to the area wide emissions.

thus the relative error in COT is:

$$E_{COT} = \frac{1}{COT} \sqrt{\left(E_{COB} COB\right)^2 + \left(E_{COL} COL\right)^2 + \left(E_{COA} COA\right)^2} \qquad \text{(G-19)}$$

where $E_{COB}$ is the expected relative error in background CO measurement.

$E_{COL}$ is the expected relative error in CO concentration attributable to the line source. Under the assumption of fixed meteorology this is equal to

$$\sqrt{E_{ef}^2 + E_g^2}$$

with $E_{ef}$ and $E_g$ the expected relative error in, respectively, auto emission factor and gate capacity of the gate causing the queue.

$E_{COA}$ is the expected relative error in CO concentration attributable to the area source. This is derived below.

Under the assumption of a fixed meteorology, COA is directly proportional to emission intensity Q. Hence:

$$COA = K \frac{ef\ V\ RT}{A} cf \qquad \text{(G-20)}$$

where K is a fixed and precise proportionality constant

A is the area of the complex and is also assumed to be final and precise

ef, V and RT are respectively auto emission factor, traffic volume and vehicle running time

cf is the correction factor applied when exit capacity and/or parking capacity is exceeded.

Thus the expected relative error $E_{COA}$ is:

$$E_{COA} = \sqrt{E_{ef}^2 + E_V^2 + \left(\frac{1}{RT}\right)^2 \left[ \left(E_{BRT} BRT\right)^2 + \left(E_{ART} ART\right)^2 + \left(E_C C\right)^2 \right] + E_{cf}^2} \qquad \text{(G-21)}$$

where $E_{ef}$, $E_V$ and $E_{cf}$ are respectively, expected relative errors in auto emission factor, traffic volume, running time and correction factor. Note that the term $E_{RT}$ (expected relative error in running time) has been replaced by its expansion in terms of more basic parameters so that:

BRT and $E_{BRT}$ are base running time and expected relative error in base running time.

ART and $E_{ART}$ are added running time due to congestion and expected relative error in same.

C and $E_C$ are added running time due to traffic signal and expected relative error in same. RT is total vehicle running time.

Finally, the term $E_{ART}$ can itself be expanded in terms of expected relative errors in traffic flow (at gates) and gate capacities:

$$E_{ART} = \sqrt{E_T^2 \left[1 + \left(\frac{a}{1 - a}\right)^2\right] + E_g^2 \left[1 + \left(\frac{1}{1 - a}\right)^2\right]} \qquad \text{(G-22)}$$

where $E_T$ and $E_g$ are, respectively, expected relative errors in traffic flow and gate capacity.

a is the utilization ratio of traffic flow to gate capacity (T/g).

In summary then the determination of $E_{COT}$ (expected relative error in CO prediction) proceeds as follows:

$$E_{ART} = \sqrt{E_T^2 \left[1 + \left(\frac{a}{1 - a}\right)^2\right] + E_g^2 \left[1 + \left(\frac{1}{1 - a}\right)^2\right]}$$

$$E_{COA} = \sqrt{E_{ef}^2 + E_V^2 + \left(\frac{1}{RT}\right)^2 \left[\left(E_{BRT}BRT\right)^2 + \left(E_{ART}ART\right)^2 + \left(E_C C\right)^2\right] + E_{cf}^2}$$

$$E_{COT} = \frac{1}{COT} \sqrt{\left(E_{COB}COB\right)^2 + \left(E_{ef}^2 + E_g^2\right) COL^2 + \left(E_{COA}COA\right)^2}$$

Where the following symbols are used:

a - utilization ratio (T/g)
ART - added running time due to congestion
BRT - base running time
C - added running time due to traffic signals
cf - correction factor when gate capacity and/or parking capacity is exceeded
COA - CO concentration attributable to area wide emissions from the complex
COB - background CO concentration
COL - CO concentration attributable to emissions from a nearby line source
COT - total predicted CO concentration
ef - auto emission factor in gm CO per minute
g - gate capacity
RT - vehicle running time
T - traffic flow at gates
V - traffic volume drawn by the complex

and in general the symbol $E_i$ refers to the expected relative error in parameter i.

## Sensitivity Equations

Having evaluated the precision of the model prediction in terms of the precision of the input parameters, it is now of key interest to determine the sensitivity of this precision to each of the input parameter precisions. In this way the more important parameters can be identified and flagged for more careful evaluation. By application of the sensitivity relationships developed in subsection "Sensitivity and Precision Analysis Methodology" above, the following sensitivities were developed. In each case the equation expresses the sensitivity of the model precision in predicted total CO concentration to the precision of the parameter in question.

- Base running time

$$\frac{\partial E_{COT}}{\partial E_{BRT}} = \left(\frac{BRT \cdot COA}{RT \cdot COT}\right)^2 \frac{E_{BRT}}{E_{COT}} \qquad \text{(G-23)}$$

Note that the greater the fraction of total running time that is the base running time, the more important is this parameter.

- Added running time due to traffic signals

$$\frac{\partial E_{COT}}{\partial E_{C}} = \left(\frac{C \cdot COA}{RT \cdot COT}\right)^2 \frac{E_{C}}{E_{COT}} \qquad \text{(G-24)}$$

Again the greater the fraction of total running time that is due to traffic signals, the more important will be this parameter.

- Correction factor for exceeded gate and/or parking capacity

$$\frac{\partial E_{COT}}{\partial E_{cf}} = \left(\frac{COA}{COT}\right)^2 \frac{E_{cf}}{E_{COT}} \qquad \text{(G-25)}$$

The greater the area source configuration to total CO measurement, the more important will be this parameter.

- Background measurement

$$\frac{\partial E_{COT}}{\partial E_{COB}} = \left(\frac{COB}{COT}\right)^2 \frac{E_{COB}}{E_{COT}} \qquad \text{(G-26)}$$

- Auto emission factor

$$\frac{\partial E_{COT}}{\partial E_{ef}} = \left(\frac{COL^2 + COA^2}{COT^2}\right) \frac{E_{ef}}{E_{COT}} \qquad \text{(G-27)}$$

The greater the line and area source contributions are to total CO, the more important will be this parameter.

- Gate capacity

$$\frac{\partial E_{COT}}{\partial E_g} = \left(\frac{ART \cdot COA}{RT \cdot COT}\right)\left[1 + \left(\frac{1}{1-a}\right)^2\right]\frac{E_T}{E_{COT}} \qquad \text{(G-28)}$$

The most significant part of this equation is the term $\left(\frac{1}{1-a}\right)^2$. As a (utilization factor) approaches 1.0 this term will grow without bound. It is evident therefore that at high utilization factors this parameter (gate capacity) will become one of the most sensitive input variables in the model. The same comment applies to the next parameter.

- Traffic flow

$$\frac{\partial E_{COT}}{\partial E_T} = \left(\frac{ART \cdot COA}{RT \cdot COT}\right)\left[1 + \left(\frac{a}{1 - a}\right)^2\right]\frac{E_T}{E_{COT}} \tag{G-29}$$

As in the case of the gate capacity parameter, traffic flow will become one of the most sensitive parameters of the model when utilization factor (a) approaches 1.0. The physical significance of this is clear. As gate capacities are approached or exceeded traffic will queue for exit or parking and, as a result, vehicle running times will increase suddenly. Changes in CO predictions will reflect primarily the increase in traffic congestion.

- Traffic volume

$$\frac{\partial E_{COT}}{\partial E_V} = \left(\frac{COA}{COT}\right)^2 \frac{E_V}{E_{COT}} \tag{G-30}$$

## SAMPLE SENSITIVITY ANALYSIS

As an example of the sensitivity analysis developed above, the Landmark Shopping Center data presented in the GEOMET study and in the EPA report will be studied by this method. The initial step in this analysis is to develop estimates of the precision of the various input parameters. Unless a better basis for estimating these is available, a standard ± 10% may be assumed for all parameters. For this example we will use ± 10%. Thus the following parameter and precisions are cited for this example (8-hour average).

1. Background CO (COB) = 0 and $E_{COB} = 0$.
2. CO contribution from adjacent line source (COL) = 0 and $E_{COL} = 0$.
3. Auto emission factor = 16.2 g/min and $E_{ef} = 0.10$.
4. Traffic volume (V) = 0.67 veh/sec and $E_V = 0.10$.
5. Base running time (BRT) = 270 sec and $E_{BRT} = 0.10$.
6. Added running time due to traffic signals (C) = 22.5 sec and $E_C = 0.10$.
7. Mean traffic flow (T) = 0.08 veh/sec and $E_T = 0.10$.
8. Mean gate capacity (g) = 0.25 veh/sec and $E_g = 0.10$.
9. From 7 and 8 utilization factor (a) = 0.30.

Thus added running time due to congestion is

$$ART = \frac{1}{0.25}\left(\frac{0.30}{1 - 0.30}\right) = 2 \text{ seconds}$$

and

$$E_{ART} = \sqrt{(0.1)^2\left[1 + \left(\frac{0.3}{1 - 0.3}\right)^2\right] + (0.1)^2\left[1 + \left(\frac{1}{1 - 0.3}\right)^2\right]} = 0.21$$

from equations (6) and (G-22). Thus total running time is

$$RT = 2 + 22.5 + 270 = 295 \text{ seconds.}$$

Calculating the CO contribution due to area wide emissions (COA) we get 8 ppm. The precision in this estimate is determined from equation (G-21):

$$E_{COA} = \sqrt{(0.1)^2 + (0.1)^2 + \left(\frac{1}{295}\right)^2\left[(0.1)^2(270)^2 + (0.21)^2(2)^2 + (0.1)^2(22.5)^2\right]} = 0.17$$

Finally, the estimated relative precision of the predicted value for overall CO concentration is equivalent to $E_{COA}$ since no background level and no emissions from adjacent roadways have been assumed. Thus

$$COT = 8 \text{ ppm and } E_{COT} = \text{about } 0.2$$

The sensitivities of this precision to the various input parameters are calculated next:

- To base running time

$$\left(\frac{270 \times 8}{295 \times 8}\right)^2 \left(\frac{0.1}{0.2}\right) = 0.42$$

- To added running time due to traffic signals

$$\left(\frac{22.5 \times 8}{295 \times 8}\right)^2 \left(\frac{0.1}{0.2}\right) = 0.003$$

- To auto emission factor

$$\left(\frac{0 + 8}{8}\right)^2 \left(\frac{0.1}{0.2}\right) = 0.5$$

- To gate capacity

$$\left(\frac{2 \times 8}{295 \times 8}\right)^2 \left[1 + \left(\frac{1}{1 - 0.3}\right)^2\right]\left(\frac{0.1}{0.2}\right) = 0.00007$$

- To traffic flow

$$\left(\frac{2 \times 8}{295 \times 8}\right)^2 \left[1 + \left(\frac{0.3}{1 - 0.3}\right)^2\right]\left(\frac{0.1}{0.2}\right) = 0.00003$$

- To traffic volume

$$\left(\frac{8}{8}\right)^2 \left(\frac{0.1}{0.2}\right) = 0.5$$

Clearly in this example the significant parameters in the model prediction are the base running time, auto emission factors and the traffic volume. This is expected since, at low levels of traffic congestion, the base operating factors will predominate.

As an example of a condition of greater congestion, consider the 1-hour average CO prediction for the same shopping center. Here the significant parameters that differ from the previous example are:

4. Traffic volume (V) = 1.01 veh/sec and $E_V$ = 0.10.
5. Base running time (BRT) = 216 sec and $E_{BRT}$ = 0.10.
7. Mean traffic flow (T) = 0.17 veh/sec and $E_T$ = 0.10.
8. Gate capacity (g) = 0.25 veh/sec and $E_g$ = 0.10.
9. From 7 and 8 utilization factor (a) = 0.70.
10. Correction factor for gate and/or parking capacity exceeded (cf) = 1.11 (from EPA report[1]) and $E_{cf}$ = 0.10.

This is added running time due to congestion

$$ART = \frac{1}{0.25}\left(\frac{0.7}{1 - 0.7}\right) = 10 \text{ seconds}$$

[illegible]

$$E_{ART} = \sqrt{(0.1)^2 \left[1 + \left(\frac{0.7}{1 - 0.7}\right)^2\right] + (0.1)^2 \left[1 + \left(\frac{1}{1 - 0.7}\right)^2\right]} = 0.43$$

from equations (6) and (G-22). Thus total running time is:

$$RT = 10 + 22.5 + 216 = 248 \text{ seconds}$$

Calculating the CO contribution due to area wide emissions (COA) we get 15 ppm. The precision of this estimate, determined from equation (G-21) is:

$$E_{COA} = \left\{ \begin{array}{l} (0.1)^2 + (0.1)^2 + \left(\frac{1}{248}\right)^2 \Big[ (0.1)^2 (216)^2 + \\ (0.43)^2 (10)^2 + (0.1)^2 (22.5)^2 \Big] + (0.1)^2 \end{array} \right\}^{1/2} = 0.20$$

Thus the estimated relative precision of the predicted value for overall CO concentration is about 0.2 since both background levels and emissions from adjacent roadways have been assumed negligible. Thus

$$COT = 15 \text{ ppm and } E_{COT} = 0.20$$

The sensitivities of this precision to the various input parameters are calculated next:

- To base running time

$$\left(\frac{216 \times 15}{248 \times 15}\right)^2 \left(\frac{0.1}{0.2}\right) = 0.38$$

- To added running times due to traffic signals

$$\left(\frac{22.5 \times 15}{248 \times 15}\right)^2 \left(\frac{0.1}{0.2}\right) = 0.004$$

- To auto emission factor

$$\left(\frac{0 + 15}{15}\right)^2 \left(\frac{0.1}{0.2}\right) = 0.5$$

- To gate capacity

$$\left(\frac{10 \times 15}{248 \times 15}\right)^2 \left[1 + \left(\frac{1}{1 - 0.7}\right)^2\right] \left(\frac{0.1}{0.2}\right) = 0.01$$

- To traffic flow

$$\left(\frac{10 \times 15}{248 \times 15}\right)^2 \left[1 + \left(\frac{0.7}{1 - 0.7}\right)^2\right] \left(\frac{0.1}{0.2}\right) = 0.005$$

- To traffic volume

$$\left(\frac{15}{15}\right)^2 \left(\frac{0.1}{0.2}\right) = 0.5$$

- To correction factor for exceeded gate and/or parking capacity

$$\left(\frac{15}{15}\right)^2 \left(\frac{0.1}{0.2}\right) = 0.5$$

Since the complex still is operating well below its capacity (utilization factor is 0.7), gate capacity and traffic flow still are not highly significant parameters. For prediction of the 1-hour averages, however, it is evident that they are considerably more important than they were for the 8-hour average prediction.